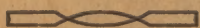


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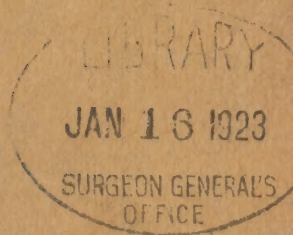
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IN
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A LABORATORY GUIDE

IN

COMPARATIVE ANATOMY

BY

HAROLD TUPPER MEAD

Associate Professor of Zoology in Tulane University of Louisiana

[New Orleans]

PUBLISHED BY THE AUTHOR

[1922]



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PREFACE.

This book is the outgrowth of a manual which was used for several years in the form of multigraphed sheets. Each year corrections and additions were made as the needs were felt.

The comparative arrangement has been adhered to throughout. That is to say, a certain system is studied comparatively in several animals before another system is begun. The shark or cyclostome is usually the starting point for the study of each system, then the study is carried successively to a tailed amphibian, snake, mammal, for which the cat or dog is used, and finally to the human manikin.

The order in which the systems are herein taken up is the order in which the author usually teaches them. This order is nothing other than the order in which the systems are naturally encountered in dissecting: integument, muscle, digestion, etc. In this order much material is conserved. However, any instructor can easily take up the study of the system in any order he chooses regardless of the order followed herein.

This manual presupposes Kingsley's Comparative Anatomy as an accompanying text. Newman's Vertebrate Zoology and Hegner's College Zoology are advised for collateral reading.

This manual is not to be thought of as a treatise on Comparative Anatomy. It is merely a guide to dissection and study.

I am glad to acknowledge at this time the most generous and valued assistance from Miss Carmen Delgado, Miss Lucile Reed and Mrs. Mead in making the drawings.

H. T. MEAD,
Tulane University.

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LIST OF ANIMALS.

Below is a list of animals required in this course for ten students: 2 lamprey eels, 5 sharks, 2 stingarees, 2 perch, 2 catfish, 5 urodeles (*Amphiuma*, *Cryptobranchus* or *Necturus*), 2 frogs, 2 snakes, 1 pigeon, 5 cats or dogs.

The smaller animals may be kept in crocks. The cats or dogs will require a larger receptacle, such as a tub or garbage can. The specimens must be kept immersed. This is especially necessary at the beginning of the course when the material is still somewhat fresh. If necessary use weights. The most economical preserving fluid is 5% formaldehyde, to which may be added a few cubic centimeters of carbolic acid. At the slightest suggestion of decomposition the fluid should be renewed.

LIST OF MICROSCOPIC SLIDES.

An understanding of the microscopic structure of organs and tissues is of prime importance. Although the following array of slides may at first thought seem rather expensive it should be remembered that there is no better method of learning the structure of a tissue than from the tissue itself. These slides should be purchased for about forty cents each, and it is not necessary for a laboratory to have on hand as many sets of slides as there are members in the class. The work can be carried on very effectively if there is only one slide to about five students.

Frog embryo, yolk plug stage, sagittal section.

Frog embryo, sucker stage, transverse section.

Chick embryo, 48 hours, whole mount.

Chick embryo, 48 hours, transverse section, serial mount.

Pig embryo, 26 mm., transverse section through meso- and metanephros.

Skin of *Amphiuma*, transverse section.

Skin of scaly fish, transverse section, scale implantation.

Lateral line of fish, transverse section.

Skin of lizard, transverse section, epidermal scales, pigment.

Skin of human scalp, transverse section, follicles, glands.

Embryonic tooth of pig, sagittal section, enamel organ.

Tongue of rabbit, transverse section, taste buds.

Oesophagus, Amphiuma, transverse section, stratified epithelium.

Stomach, Amphiuma, transverse section, stomach glands.

Small intestine, Amphiuma, transverse section, goblet cells.

Large intestine, cat, transverse section.

Liver, pig, lobules.

Liver, blood vessels injected.

Pancreas, pig, tubules.

Gill, Necturus, general structure.

Trachea, kitten, longitudinal section, cartilage rings.

Lung, cat, air sacs.

Thyroid gland, dog, alveoli.

Mesonephros, Amphiuma, large glomeruli.

Bladder, Amphiuma, transverse section, large cuboid cells.

Ovary, Amphiuma, large ova.

Oviduct, Amphiuma, transverse section, coarse epithelium.

Ovary, cat, follicles, oocytes.

Cervix of uterus, longitudinal section.

Testis, Amphiuma, developing spermatocytes.

Testis, rat, Sertoli cells.

Artery, vein and nerve, transverse section, various layers.

Blood smears of man, mouse, deer, horse, frog, Amphiuma, camel.

Spinal cord, bear or man, transverse section, motor cells.

Cerebellum, Purkinje cells.

Eye of frog, sagittal section, retina, lens.

Olfactory epithelium, dog.

Much of the dissecting material can be provided by students if teachers find it necessary to economize.

Dissecting material and microscopic slides can be purchased from:

(1) Southern Biological Supply Co., Inc., Natural History Museum, New Orleans, La.

(2) General Biological Supply House, 1177 East Fifty-fifth street, Chicago, Ill.

Both of these houses will be glad to submit estimates for providing the above dissecting material and prepared slides.

TO THE STUDENT.

About Dissecting Instruments. You will need the following dissecting instruments:

- 1 Substantial scalpel.
- 1 Medium dissecting forceps.
- 1 Seeker or probe.
- 1 Scissors, one sharp and one blunt point.
- 1 Bone cutting forceps.

The last item is the most expensive and the least often used, so one pair may be shared by a group. Do not go to the needless expense of purchasing elaborate sets or operating sets. Keep your instruments clean.

About Drawing Material. Provide yourself with a good quality of drawing paper, 8½x11 inches, a 4H drawing pencil, an eraser and a celluloid ruler. Always use the metric system.

About Dissecting. A comparative anatomy laboratory usually has the undeserved reputation of being the "place where they cut up cats." Very little cutting is actually done. The object on the part of the dissector is to display structure. This is accomplished by carefully separating structures from surrounding tissue. A ligament or organ hastily cut might prove to be a handicap for the future understanding of the relationship of the parts. The probe is your most valuable ally.

About Care of Material. The specimens provided you are to remain in your possession. It is decidedly to your own interest to take proper care of the material. Before leaving the laboratory see that all your dissecting material is immersed in the preserving fluid. It should never be allowed to dry out. Keep your dissecting table clean. Deposit all waste material in receptacles provided.

About Drawings. Numerous drawings are required throughout the manual. At times the student is prone to doubt the necessity of making many drawings. The author believes that there is no more efficient avenue to knowledge of form and structure than to observe and at once translate that observation into a drawing. The process enjoins accuracy of observation

and a definite mental image. Therefore your observations, nay even your knowledge of the form and structure of the object at hand may be measured by the accuracy of your drawings.

About References. The references used in this manual are:

K.—Kingsley, Comparative Anatomy.

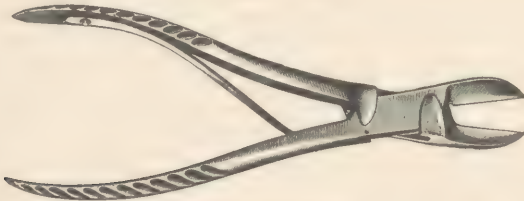
N.—Newman, Vertebrate Zoology.

H.—Hegner, College Zoology.

You are required to possess or have access to the Kingsley text. The two other texts, although not required, are valuable for collateral reading.



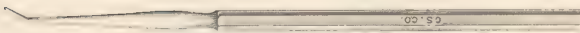
CARTILAGE KNIFE



BONE FORCEPS



SCISSORS



PROBE



SCALPEL



DISSECTING FORCEPS

Dissecting instruments recommended for this course. Loaned through the courtesy of the Central Scientific Company.

MUSEUM EXERCISE ON CLASSIFICATION AND GENERAL CHARACTERISTICS OF THE VERTEBRATES.

Inasmuch as the work of the course deals almost absolutely with vertebrates it is highly important for the student to become familiar at the outset with the various classes and orders of vertebrates. The most practical manner in which to do this is to examine representatives from each class and order, and the student should satisfy himself that he knows one or two of the essential characteristics of each group.

For the first laboratory period preserved or stuffed specimens will be provided, but for the larger forms which are to be studied the second day, recourse must be had to a museum.

CLASS, CYCLOSTOMATA.

Examine the specimens of cyclostomes provided. What is the general shape? Observe the position and structure of the mouth. Are jaws present? Are teeth present? What could such a mouth be used for? What does the word "cyclostome" mean? (K. Definition of Scientific Names, page 417, and Roots of Technical Words, page 423.) How many nostrils are present? Are eyes present? Are paired fins present? Is there a well developed dorsal fin? Determine to which sub-class, the Petromyzontes or the Myxinoidei, belong the specimens which are provided (K. 4: N. 89 ffg.).

CLASS, PISCES.

Sub-class, Elasmobranchii.

Examine an exhibit of dogfish, sharks and stingarees. Is the position of the mouth similar in all specimens provided? Observe the arrangement of the lobes of the tail, and whether or not this arrangement is common to all elasmobranchs. What name is given to this type of tail (K. 5 and 56.) Are paired fins present? How many gill slits are there? Are the gill slits covered or naked? Examine the character of the skin by stroking it. Are scales present? Examine them with a hand lens and note the number of spines on each scale.

Sub-class, Ganoidea.

Examine specimens of the garpike. Has it a formidable mouth? What is the position of the mouth? Are the paired fins similar to those of the shark? Are the gills naked or covered with an operculum? Compare the tail with the tail of the sharks. What is the name of this type of tail (K. 56 and 57)? Observe the position of the unpaired fins. The structure of the scales is of prime importance as characteristic of ganoids. What is their shape? Do they overlap? Do they appear to be formed of the epidermis or from the under layer of the skin? (K. 44.) What is the meaning of the word "Ganoidea"?

Sub-class, Teleostei.

Practically all the food fishes belong to this sub-class. Describe the position of the mouth of all specimens observed. What does the word "teleost" mean? Are there always two pairs of paired fins? Are the pelvic fins always behind the pectorals? Is any variation in this respect ever found in the elasmobranchs or ganoids? Compare the tail lobes with those of the elasmobranchs and ganoids. Is there internal and external symmetry in the two lobes of teleosts? Does the vertebral column extend into either lobe? If so, which lobe? What name is given to this type of tail? (K. 5 and 57.) Do the scales overlap? What name is given to this type of scales? Is there an operculum?

(To be answered in the museum at the next laboratory period.) Examine a cast of a fossil *Lepidotus maximus*. To which of the above named classes or sub-classes does it belong? To which sub-class does the tarpon belong? To which does the sturgeon belong? To which does the fossil, *Mesturus verrucosus* belong? Compare according to the chart (K. 8 and N. 98) the antiquity of the last three sub-classes.

CLASS, AMPHIBIA.

Sub-class, Anura.

This subclass includes the frogs and toads. Do they possess gills or lungs? Do all members of this sub-class undergo metamorphosis, i. e., pass through a tadpole stage? Do the tadpoles possess gills or lungs? What other changes take place at metamorphosis?

Sub-class, Urodela.

Examine specimens of *Necturus*, *Ambystoma* and salamander. Do these amphibians possess tails? Do any or all of them possess external gills? Are they air or water breathers? Is the skin smooth or scaly? Are the paired appendages fins or legs?

Sub-class, Stegocephali.

Examine the illustration (K. 90) of the skull of the extinct stegocephalan amphibian, *Capitosaurus*. Are the bones of this skull more or less numerous than those of the skulls of *Amblystoma* (K. 91), toad (K. 94), turtle (K. 98)? What does the word "Stegocephalus" mean? Are there any large openings into the skull such as are seen in the skulls of the *Amblystoma*, toad and turtle? Compare according to the chart (K. 8) the antiquity of the three sub-classes of the amphibians mentioned above.

CLASS, REPTILIA.

Order, Chelonia.

These are more commonly called turtles. What is a common characteristic of all turtles? Do turtles possess teeth? Can the body of all or any turtles be entirely enclosed within the shell? Are the feet webbed in any or all of the species? What would you judge to be the habitat of those turtles which possess webbed feet? Those entirely without webs? Are the head, neck, legs, feet and tail scaly? What does the word "Chelonia" mean?

Order, Squamata.

This order includes the snakes (*Ophidia*) and the lizards (*Lacertilia*). The student should endeavor to decipher the essential structural differences between the snakes and lizards. Examine specimens of snakes and lizards as to body proportions, eyelids, appendages, anus, belly scales. Make (1) a list of those features in which snakes and lizards differ from each other, and (2) a list of those feature in which they resemble each other. From your own observations state whether snakes or lizards can open their mouths the wider.

At this point the work must be resumed in the museum.

In skeletons of snakes and lizards examine and make a sketch of the apparatus by means of which the lower jaw is

attached to the upper portion of the skull. Observe that there is a link between the lower jaw and the skull. Would you consider this to be a weak or a strong attachment? (N. 255; H. 560.) What is the meaning of the word "Squamata"?

Extinct Reptiles.

Extinct reptiles of various orders are on exhibition in the form of fossils, casts of fossils or plastic reproductions. A few genuine bones of ancient reptiles may be encountered.

Observe the size and general body proportions of the Plesiosaurs, Ichthyosaurs, and Teleosaurs. Which group contains the largest individuals? Which the smallest? Which group seems to resemble most closely the fish? Which is more decidedly reptilian? Compare the feet of each group. From your observations of the feet what would you judge to be the habitat of each group? In the skeletons of the appendages of the Plesiosaurs and the Ichthyosaurs do you find relatively few or many bones?

Observe the tracks of the Dinosaurs. What would you judge to be the habitat of the Dinosaurs, land or water? (N. 219 ffg.) Which group has the longest and most snake-like neck? Which group has the longest tails? Which the shortest? Scales of the Teleosaur are on exhibition in the museum, but it is doubtful whether or not the Plesiosaur and Ichthyosaur had scales.

According to the chart (K. 8 and N. 211) compare the antiquity of all the above mentioned groups of reptiles. List the reptiles according to the order of their appearance upon the earth and also according to their disappearance. Are your two lists the same? Were the earliest reptiles the first to pass out of existence?

CLASS, AVES.

What single characteristic is sufficient to characterize all birds? What type of mouth is common to all birds? Can all birds fly? Do all birds possess wings? What purpose is served by the wings of the ostrich? By the wings of the penguin? (N. 293.)

Examine casts of the fossil of the extinct bird, Archaeopteryx, and the illustration of the Hesperornis (N. 279) and the Ichthyornis (N.290). Are teeth present in any or all of these ancient birds? Do you know of any extant bird which has

teeth? How many toes have most birds? How many has the ostrich?

Examine a cast of the fossil of the *Rhamphorhynchus*. Notice that some of the integument has been preserved in the fossil. Do you see any feathers associated with the integument? Do you believe that this creature did or did not possess feathers? Observe the long, slender tail. What do you judge to have been the function of the triangular structure at the tip? Are teeth present? How would you classify the *Rhamphorhynchus*?

CLASS, MAMMALS.

Examine several mammals in the museum for the presence of hair. Does the armadillo possess hair? Does the walrus possess hair? What generalization can you make as to the presence of hair on mammals? Examine the feet of the beaver, duckbill, horse, moose, camel, elephant, opossum, ape and man. Are you able to generalize as to the character of feet of mammals? How many toes have apes, spider monkeys, lions, rhinoceros, moose, sloth, tapir, horse?

Examine the mouth of the duckbill. Is it at all comparable to the mouth of most other mammals?

How many cervical vertebrae (i. e., between the skull and first rib) has the elephant, horse, lion, monkey, sloth, seal and man? Make a generalization with one exception.

Describe the simple manner of attachment of the lower jaw to the upper. How does this mechanism compare with that found in reptiles?

Observe how completely the eye socket is enclosed in the lion, bear, tapir, horse, apes and man. Generalize.

Observe whether the ribs are articulated with or solidly attached to the vertebrae. Compare with the fish skeleton.

Where are the mammary glands situated in cow, cat, kangaroo, ape, man, whale and elephant? What is the meaning of the word "mammal"?

What is the geologic history of the monotremes as compared with the other mammals?

The orders of mammals here given should be familiar to every zoologist. (1) Monotremata, egg laying, duckbill, *Echidna*. (2) Insectivora, small insect eaters, moles, shrews,

and old world hedgehog. (3) Chiroptera, small flying mammals, bats. (4) Carnivora, those mammals possessing sharp teeth adapted for tearing meat, cats, hyena, weasel, bears, raccoon, dogs, foxes, seals. (5) Rodentia, incisor teeth adapted for gnawing, rats, squirrels, ground hog, porcupine, guinea pig, rabbits, beaver, agouti. (6) Edentata, mostly toothless anteaters, sloth, true anteaters, armadillo. (7) Primates, mammals walking upright for the most part, possessing nails instead of claws, monkeys, apes and man. (8) Artiodactyla, even toed, hoofed mammals, pigs, cattle, deer, giraffe, camel, hippopotamus. (9) Perissodactyla, odd toed ungulates, horse, tapir, rhinoceros. (10) Proboscidea, provided with a proboscis or trunk, elephant. (11) Sirenia, marine mammals feeding on vegetation, manatee, dugong. (12) Cetacea, marine mammals feeding on flesh or small floating organisms, whales.

INTRODUCTORY EMBRYOLOGY.

Cleavage (K. 7; N. 205).

To each student will be given some frog's eggs in that stage of development known as cleavage. Each cleavage mass consists of somewhere between 64 and 1,000 cells. These cells are easily visible under a hand lens or under the low power of a compound microscope. If possible determine the exact number of cells present. Most likely one-half or more of the egg will be black while the remaining portion will be light. The dark area marks the so-called animal pole, while the white area marks the so-called vegetal pole. Are the individual cells (blastomeres) of uniform size? If you find a variation in size of the blastomeres determine whether the animal pole is composed of the larger or smaller cells. Record your observations by means of a sketch.

Confine the egg gently between the points of blunt forceps and by means of a sharp scalpel bisect the egg. With the hand lens or the low power of the microscope examine the inside of the egg. Is it hollow? Such a cavity formed inside a segmenting egg is called a segmentation cavity. Is it exactly in the center of the egg? Observe at this time how deeply the pigment penetrates the substance of the egg.

Gastrulation.

For this study secure gastrulation or yolk plug stages of frog's eggs. At this stage of growth the dark area has increased until the white area is reduced to a small, circular plug known as the yolk plug. In the living egg it is at this time disappearing beneath the encroaching layer of pigmented cells. This process whereby the white cells penetrate the interior of the egg and the dark cells extend themselves superficially around the white ones, is known as gastrulation. The dark cells, making up the animal pole, proliferate more rapidly than do the white ones of the vegetal pole, which results in the dark cells extending themselves superficially towards the vegetal pole. Is there a regular or uniform arrangement of the cells composing the gastrula? Are they of uniform shape or size?

The vertical plane of the gastrula may be distinguished by the presence of a groove extending from the crescent opening around the yolk plug (blastopore) forward along the back. This groove, when it first appears, is called the primitive streak, but after it has deepened itself by means of its sides becoming higher it is called the neural groove and is the forerunner (anlage) of the spinal cord, brain and entire nervous system.

Record your observations of the gastrula by means of a sketch. All the above mentioned structures should be indicated in your sketch.

Bisect the gastrula in a vertical plane through the yolk plug. Examine the inside with a hand lens or low power of the microscope. Has the segmentation cavity disappeared? Are you able to distinguish a second cavity connecting through the canal to the blastopore to the outside? This second cavity is the archenteron and is the anlage of the digestive tract, and its opening canal, known as the blastopore, marks almost the extreme posterior end of the intestine. The anus will develop as a persistent opening slightly posterior to the blastopore.

Germ Layers.

Gastrulation produces two distinct layers of cells, (1) the ectoderm, the outer layer which originates in the animal cells, and (2) the endoderm, the inner layer or mass which originates in the vegetal cells. There is a third layer, the mesoderm, which subsequently arises between the ectoderm and the endoderm. These three layers, ectoderm, endoderm and mesoderm, are found in the developing embryos of all vertebrates and from them the various organs and tissues of the body arise. For this reason an understanding of the origin and morphology of the germ layers is fundamental.

The mesoderm in time acquires a cavity which extends itself entirely around the archenteron. This cavity, entirely surrounded by mesoderm, is called the coelome. In amniote vertebrates there is a portion of the coelome which extends outside the embryo proper and around the yolk sac and is called the extra embryonic coelome.

The layer of mesoderm immediately adjacent to the coelomic cavity becomes a single celled layer (epithelium) known as the peritoneum.

Make a drawing from a slide of a vertical section of a gastrula of the frog. With colored crayons or inks represent the ectoderm in blue, endoderm in yellow and the mesoderm in red. All structures mentioned above either under the subject of gastrulation or germ layers should be included in this drawing if present.

Organogeny.

From the germ layers the various organs and systems arise as follows:

From the ectoderm arise—the epidermis, enamel of the teeth, outer portion of hoofs, nails, claws, horns, the hair, the lens of the eye, lining of the mouth and nasal passages, the salivary glands, the entire nervous system including the nervous parts of all the sense organs and the neuroglia.

From the endoderm develop—the mucous membrane lining of the oesophagus, stomach and intestine, larynx, trachea and lungs, the glandular epithelium of the liver and pancreas.

From the mesoderm arise the muscles, bones, cartilage, dentine, the circulatory system including the blood, all connective tissues and serous membranes including the peritoneum, pleurae, mesenteries and omenta, fat, the urinary system and the internal parts of the reproductive system.

Examine a slide of a section through the middle region of a chick embryo of about forty-eight hours' incubation. A drawing of ample dimensions should be made, and labeled according to the derivation of the organs. Follow K. 11 ffg. Use colors.

In the mid-dorsal region of the chick embryo section will be recognized the large, open nerve cord. Closely ventral to this is the notochord and ventral to this may be a single or paired dorsal aorta(e). Compare Fig. 1.

The most dorsal line of tissue forming the back and sides of the embryo is to become the epidermis. The most ventral line of tissue will be the mucous lining of the stomach and intestine.

On each side of the mid line of the embryo appears a mass of cells known as the mesodermic somites. This mass is not uniformly continuous throughout the length of the embryo, but is segmented; that is to say it is divided into somites. The most dorsal portion of each mass appears somewhat more thickened or denser than the remainder of the mass and is destined to give

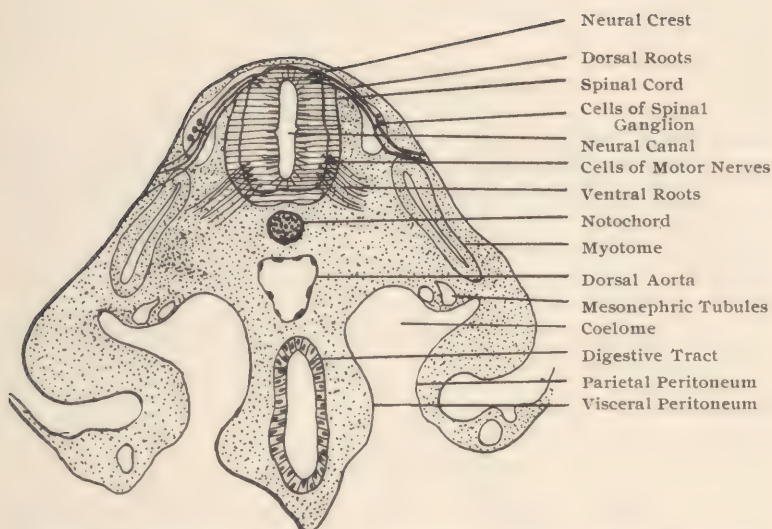


FIG. 1. Transverse section of mammalian embryo showing development of organs.

rise to muscle. That portion of the somite is known as the myotome. The most medial portion of the somite, viz: that portion which tends to enclose the notochord and nerve cord is destined to become bone of the vertebral column. That portion of the somite is known as the sclerotome. The more distal portion of the somite, more particularly the point where it seems to narrow down to a neck, will give rise to the urinary and reproductive systems. This region is known as the nephrotome. The nephrotomes are usually marked by a mass of cells composing tubules which appear on the dorsal side of the somite at this region.

Lateral to this point the mesoderm divides into a dorsal and a ventral plate, leaving the coelome between. In the chick it is readily possible to distinguish the embryonic coelome from the extra embryonic coelome. The dorsal plate will become the parietal peritoneum, i. e., the lining of the coelomic cavity. In the region of the lungs this would be the pleurae. The ventral plate will become the visceral peritoneum or serous covering of the stomach and intestines. These two layers remain continuous with each other by way of the mesentery, the membrane which suspends the intestine from the body wall. How many layers must there be in the mesentery?

HISTOLOGY (K. 21).

At a very early period in the development of the embryo the cells begin to differentiate. While the cells are assuming their respective functions this process of differentiation is increased until distinct tissues are produced. A tissue, therefore, is a portion of an organism in which cells of similar structure and function predominate.

Although the kinds of tissues found in the bodies of animals are numerous, all may be conveniently grouped into four fundamental tissues, viz: (1) epithelial, (2) nervous, (3) muscle, and (4) connective.

Epithelial Tissue.

(a) Simple Columnar. Examine slide preparations of sections of the wall of the intestine. The inner layer, called the mucous membrane, is composed of columnar cells. Endeavor to visualize the three dimensions. What is the shape of columnar cells as solids? Are granules present?

(b) Stratified Epithelium. Examine slide preparations of bladder tissue. The lining membrane is composed of several layers of cuboid cells. What is the shape in the solid of these cells?

(c) Simple Squamous Epithelium. Examine pieces of the shed skin of a frog, or the peritoneum of some animal. The tissue should be soaked in silver nitrate and exposed to the sun for a few minutes before examining. This treatment renders visible the material between the cells. Do these cells overlap each other?

(d) Glandular Tissue. Glandular tissue is epithelial tissue which has become modified to secrete or excrete. A small grain of pancreas should be finely teased apart by means of two dissecting needles, and treated with methylene blue. The individual cells will be easily seen. Can you distinguish granules?

(e) Reproductive Tissue. Examine the ovary of some amphibian or fowl. Identify the developing yolk laden ova.

What is their shape? What is the significance of their relatively large size?

Nervous Tissue.

Nerve trunks are bundles of nerve fibers, each fiber of which is the axone of a nerve cell. Most axones are covered with a sheath composed of a fatty material called myelin, and outside the myelin sheath is an exceedingly thin membrane known as the neurolemma. The myelin sheath is interrupted at intervals of about one millimeter (Nodes of Ranvier), but the neurolemma is continuous. The essential nerve tissue occupies a relatively small space at the center of the fiber and is called the axis cylinder.

Secure a small piece of nerve trunk from the lumbar plexus of some animal. With two needles separate the fibers. Apply a drop of Sudan III and cover. Sudan III stains fatty tissues red.

Draw a nerve fiber showing the axone, axis cylinder, myelin sheath, node of Ranvier. From which germ layer does the nervous system arise? From which germ layer does the myelin sheath arise? (K. 24.)

The bodies of nerve cells are irregular masses of protoplasm possessed of one or more processes called poles. Thus nerve cells are spoken of as unipolar, bipolar and multipolar, depending upon the number of poles they possess. One process invariably is the axone, other processes are the dendrites. Impulses ordinarily enter the cell body through the dendrites and leave through the axone. The nuclei of nerve cells are large and nearly colorless with their chromatin material condensed into a single nucleolus, a condition which is commonly interpreted as the resting phase.

Examine (miscroscopic slides) three types of nerve cell bodies as follows:

(a) Motor cell. These cells are found in the ventral horn of the gray matter of the spinal cord. In case this slide or any of the slides examined are stained according to the Nissl method the base of the axone may be distinguished from the dendrites by the fact that there are no granules visible about the axone while they are abundant about the dendrites. Several processes of the motor cells can be distinguished.

(b) Retina cells. Large cells of the bipolar type can be found in layers. These cells are sensory in function, therefore they convey their impulses inward towards the brain.

(c) Purkinje cells. These are large cells from the cerebellum. The dendrites are highly branched and extend towards the cortex of the cerebellum while the axones extend into the central fiber tracts.

Neuroglia is the name applied to the supporting tissue found between the nerve elements of the brain and cord. It is of ectodermal origin.

Muscle Tissue.

Muscle tissues are classified as follows:

- (a) Voluntary striated.
- (b) Involuntary striated (cardiac).
- (c) Smooth.

To study voluntary striated muscle soak a small piece of voluntary muscle, preferably from the diaphragm of a dog or cat or the leg of a grasshopper, in caustic soda to soften and macerate. Place a piece no larger than the head of a pin on a slide. Tease the fibers apart. Cover and examine. Are cross striations visible? Are the fibers straight or wavy? branched or simple? To see the nuclei of striated muscle examine a prepared slide stained with hematoxylin. Are there more than one nucleus to a cell?

In a similar manner treat and examine cardiac muscle from the heart of some animal.

Similarly treat and examine smooth muscle which may be obtained from the outer wall of the stomach of any vertebrate animal.

Answer the above questions for cardiac and smooth muscle.

Connective Tissue.

Of the four fundamental tissues, connective tissue is the most diversified. The chief characteristic of all connective tissues is the separateness of the cells and the existence between the cells of a substance called matrix. Connective tissues are classified as follows:

(a) mucous, (b) areolar (loose), (c) tendon, (d) adipose (fat), (e) cartilage, (f) bone. Representative tissues may be selected and studied as follows:

Areolar. Secure a piece of subcutaneous or intermuscular areolar connective tissue. Place a small piece on a slide, apply a drop of water, tease, cover and examine. A tangle of fibers will be seen. If stained with chrome-acetic acid followed with acid fuchsin the connective tissue cells will be stained red. Two types of fibers may also be distinguished: (1) the white non-fibrous variety and (2) the yellow elastic variety. Pay particular attention to the matrix. Is it solid or fluid or watery?

Adipose. This tissue may be blackened in dilute (1 per cent) solution of osmic acid or stained pink with Sudan III. The cells of adipose tissue consist of a droplet of oil enclosed in a thin protoplasmic capsule. The nucleus may occasionally be seen in the wall of the capsule. For this study use fat obtained from the body of a cat or dog or a piece of tallow. Tease the particle to be examined, while applying the stain. A heaped up mass of small spheres should be seen. In cross section what kind of figures would these spheres present? Observe fat tissue from prepared slides. Make a sketch.

Cartilage. Examine a slide of cartilage. The matrix is dense as compared with either areolar or adipose. The cells usually stain differentially and on prepared slides may be seen occupying small spaces in the matrix called lacunae. Are fibers visible in the matrix? Summarize the characteristics of connective tissue.

From this point on the anatomy of the various vertebrates will be studied by systems. Each student or group of students will be provided with a set of preserved vertebrates including a cyclostome, a fish, a tailed amphibian, a reptile, a pigeon and a small dog or cat. Students will be provided with no other material or specimens, therefore it is decidedly to the advantage of the student to take proper care of his material. All specimens should be returned to the preserving fluid at the close of work and carefully immersed. Material once dried out can never be recovered.

Keep your table scrupulously clean. All scraps should be thrown into waste jars.

The systems will be studied in the following order: integument, muscles, digestive system, respiratory system, urogenital system, circulatory system, skeleton, nervous system.

As a rule no part of the body excepting fat, skin and connective tissue should be discarded while dissecting until the study of the skeleton is reached. Do not cut an organ out in order to obtain a better view of it. Its relation to other parts is of exceeding importance. Particular care should be exercised to preserve intact the blood vessels. It is usually desirable to inject the blood vessels with a colored starch mass in order to make them stand out full and to differentiate them, veins from arteries.

INTEGUMENT (K. 29).

The integument is the covering of the body. It includes the skin and all excrescences of the skin such as horns, scales, shells, hoofs, claws, nails, hair and feathers. It is essentially protective in function and offers numerous examples of adaptation to environment. Thus the skin of aquatic animals is soft, while that of land animals is relatively hard.

Examine the integument of an amphibian. Is it hard or soft? Scaly or smooth? In life is it dry or slimy? Examine the feet and head for any excrescences. Examine a prepared slide of the vertical section of the skin of an amphibian. Identify the various layers and structures (K. 30). Make a sketch showing details of structure. Are chromatophores present? Explain the function of the periderm, the generative layer and the corium.

Are blood corpuscles visible? In which layer? Find dermal glands. Is there any evidence that they are connected by ducts to the outside? With which layer of the skin is the lining of these glands continuous? After handling a live frog, what would you judge to be the function of these glands? What advantage is there to the frog to possess such glands?

Are scales visible in the skin of cyclostomes?

Stroke the skin of a shark in both the anterior and the posterior directions. Are scales present? Examine the skin with a lens. If scales are present describe them and classify them. (K. 44.)

Classify scales, if present, on perch, sucker, trout, catfish, sturgeon, red snapper, garpike, porcupine fish.

Examine a slide of the skin of a scaly fish. Note that the scale is embedded in the corium and consists of a single layer of modified bone-like material devoid of enamel. Compare the figure 203 (K. 195). It is, therefore, composed exclusively of dermal material, and properly belongs not to the integumental system but to the exoskeleton.

Extending along the side of every fish is the so-called lateral line. Find the lateral line on your specimens. Compare it on several species. Compare the figure (K. 194). It consists of a canal extending along the lateral line in the corium with an opening at intervals to the outside. Is there such an opening in each scale along the canal? The canal of the lateral line is well supplied with nerves and doubtless functions as a receptor of sensations arising from current, water disturbances, etc. The lateral line may be traced forward onto the head, where usually three distinct branches may be distinguished, (1) the supraorbital branch passing above the eye, (2) the infraorbital branch passing below the eye, and (3) the hyomandibular branch passing to the lower jaw. Examine the lateral line in cross section on a slide.

Examine the integument of snakes. Is it provided with scales? Are the scales of snakes, if present, keeled? i. e., is there an elevated ridge extending along the surface of each scale? On a rattlesnake or water moccasin find the pit in front of the eye. Does the pit appear to be connected with the orbit of the eye? Is such a pit present on any non-poisonous snake? The rattles are epidermal outgrowths. Compare the belly plates anterior and posterior to the anus on poisonous and non-poisonous snakes. Tabulate your results. Do you believe this is a safe guide in distinguishing poisonous from non-poisonous snakes?

Hold a live chameleon lizard (*Anolis*) under the low power of the microscope in order to view the changes in the color masses (chromatophores). Watch several chameleons, preferably in their natural habitat, to determine whether or not they change their color to correspond to their environment. Do you observe any colors besides brown and green? Which color is the more common? What color do they assume during periods of quiet and relaxation? Compare your results with other mem-

bers of the class. Examine a slide of the skin of a chameleon. Which pigment is superficial? What pigments are present? From a study of the slide can you understand how brown is produced by the chameleon?

Examine the shell of a turtle. The outer surface is divided into plates, sometimes called scutes. They are composed of horny material. The inside plates are extensions of the ribs and are therefore bony. Do the outer and inner plates correspond in outline? In the dorsal shell (carapace) the scutes are arranged in five longitudinal rows. The mid-dorsal row is composed of neural scutes. Lateral to the row of neural scutes are the costal scutes, while lateral to these are the marginal scutes. The ventral shell (plastron) consists of two longitudinal rows of scutes named, beginning with the most anterior, gular, humeral, pectoral, abdominal, femoral, and anal. The bony portion of the plastron is composed of the clavicles, sterna and ends of ribs. Draw the carapace and the plastron, labeling the various scutes. (N. 227.)

The parts of a feather are (1) the shaft, which is composed of a hollow basal portion known as the quill or calamus, and a distal portion filled with pith known as the rachis, and (2) the vane. The vane is composed of a series of parallel barbs which are interlocked with each other by means of barbules.

With the high power draw a small portion of the vane to show the interlocking of the barbules (K. 34).

By means of a hand lens, or the low power of the microscope, view the palmar surface of your own finger. Are the sweat pores on or between the ridges? A thumb print can be made by pressing the thumb firmly upon an inked plate, then upon white, preferably glazed, paper. A good print should show the pores when viewed through a lens. Are the patterns of the right and left thumb identical? Compare other patterns to determine whether or not you can find another pattern similar to yours.

Examine a prepared slide of human scalp. Identify the various layers, epidermis, stratum germinativum, corium. Find the root of a hair. Does the hair penetrate the epidermis or does the epidermis follow the hair root down into the follicle? Sebaceous glands are usually found near a follicle. These

glands have no open lumen. Their cells are large and colorless. That is to say that due to their oily consistency they do not take watery stains readily. Sweat glands have long, wavy ducts opening onto the surface of the skin. The gland terminates deep in the corium as a knotted tube. Make a drawing of a small section of the scalp showing the above mentioned structures.

With intense light (reflected) endeavor to see the outlines of the cells of a hair removed from your own head. The outlines usually appear as minute, indefinite cross striations. Define vibrissa.

In your own finger nail identify unguis (the nail itself), subunguis, i. e., the toughened skin found under the edge and attached to the nail, the lunula, the light, crescent area near the base of the nail not visible in all people, the eponychium, the skin which overlaps the surface of the nail.

MUSCLES.

Relatively few of the muscles will be studied. The purpose of the exercise on muscles is not only to become familiar with the name and location of a number of muscles but also to understand the facts of homology as exhibited in the muscles of various vertebrates and to behold the changes which muscles have undergone in their phylogenetic development from the simple segmental myotomic arrangement as found in the lower vertebrates to the non-segmental arrangement as found in vertebrates with well developed appendages.

Usually any given muscle should be identified first in a urodele, then it should be identified in a fish, a reptile, dog or cat, and finally on man (manikin), and occasionally on a fowl. In endeavoring to identify homologous muscles there are certain guides. Thus origin and insertion are commonly made use of. That is to say that in the event that two muscles on different animals can be shown to have identical origins and insertions those two muscles may usually be regarded as homologous. This guide is not always reliable. The nerve supply of a muscle is the surest guide to its identity and homology. Whenever a muscle migrates from its original position it always takes its nerve with it, therefore nerve supply is a certain guide to the

derivation, either embryologically or phylogenetically, of a muscle. Unfortunately it is not always practicable to trace the nerve supply of a given muscle.

In locating points on the body the following terms will be frequently used and should be understood, dorsal, ventral, cephalad, caudad, lateral, medial, superficial, deep, proximal, distal, intrinsic, extrinsic, axial. The following terms pertain more particularly to muscles, origin, insertion, flexion, extension, abduction, adduction, elevation, depression, dilation, constriction. (K. 134.)

Remove the skin from a urodele, as e. g., *Amphiuma* or *Necturus*. A general survey of the musculature of such an animal reveals the fact that the muscles are arranged in a series of blocks. The fibers extend in a longitudinal direction, but the blocks (myotomes) extend transversely around the body like a series of girdles. This series of myotomes is unbroken save only in the head and near the bases of the appendages. Here the myotomes are interrupted due to the fact that many myotomes are associated with the appendages and must needs suffer disarrangement from their simple myotomic series.

Remove the skin from a fish and snake and determine whether or not the muscles of these animals partake of the same general arrangement. In fish and snake there is a tendency for the myotomes to become zigzag. This makes it possible to distinguish a dorsal, a ventral and a lateral series of myotomes. Sometimes, as in snake, the dorsal series is decidedly darker than the other series.

The myotomes were separated embryonically from each other by a series of septa composed of connective tissue. The linear series is separated from each other by vertical septa, the dorsal series is separated from the lateral series by the longitudinal septum and the dorsal series are separated from each other by the vertical, longitudinal septum. The longitudinal, horizontal septum is indicated superficially in fishes by the lateral line. (K. 131 and fig. 33, p. 41.)

Inasmuch as this myotomic arrangement prevails in all the so-called lower vertebrates is it not evident that this was the primitive arrangement upon which all other arrangements are based? It is well to recall here that the embryos of all verte-

brates including the birds and mammals display a similar series of myotomes, but due to the appearance of well developed appendages the latter in their adult stage have departed from the myotomic arrangement. Compare the law of biogenesis.

Remove the skin from a cat or dog.¹ In doing so the student will observe that over the ribs and sides of the neck there is a superficial layer of integumental muscle which comes off with the skin (K. 139). The portion over the ribs is called the *panniculus carnosus*. The portion over the neck is called the *platysma*. The *panniculus* is found only in mammals. It is best developed in the marsupials, where it enters into the formation of the pouch. In horses and most other mammals it is the muscle which twitches the skin to shake off insects. It is decidedly reduced in monkeys and disappears in man. The *panniculus* is an offshoot from underlying muscles, viz: the *pectoralis* and the *latissimus dorsi*.

While the *panniculus* has had a retrogressive experience the *platysma* has enjoyed a progressive development. It appears to have taken origin in the sphincter coli, a small muscle which encircles the neck of amphibians, reptiles and birds. In mammals it covers the sides of the neck and separates into two divisions which pass onto the ventral and dorsal surfaces of the head. Upon encountering the mouth and eyes the muscle encircles them, forming sphincters, viz: the *orbicularis oris* and the *orbicularis oculi*. Over the forehead the frontal muscle is formed. Over the occipital region the occipital muscle is formed. The ears receive several slips which move the ears. In the apes the facial muscles are well developed and send out numerous slips which produce facial movements or expressions. In man they are still better developed. Identify these muscles of expression on the manikin.

The *platysma* and all its derivatives, viz: the muscles of expression are innervated by the VII cranial nerve (facial) (K. 188).

The ventral mass of myotomes has given rise to the following muscles which should be identified first on the dog, then on

¹Before leaving the body of the cat or dog today, be sure to open the skull with a bone saw or forceps in order that the preserving fluid may act upon the brain. Formaldehyde has a hardening effect upon nervous tissue. Also be certain to open the abdomen and thorax to permit ample penetration of the preserving fluid.

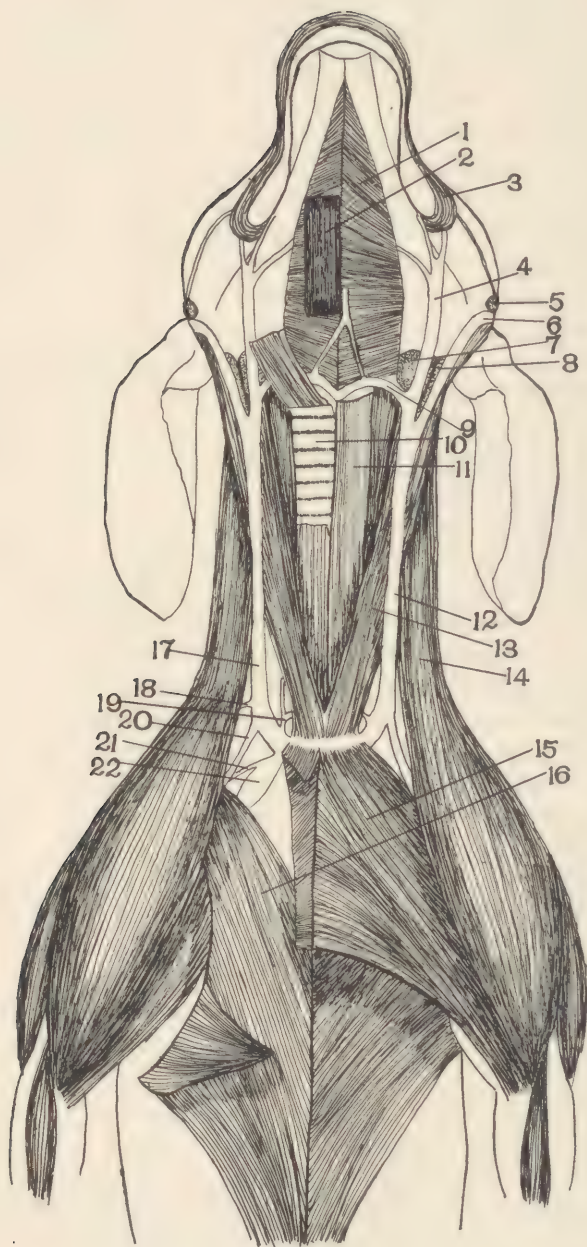


PLATE I.

the manikin, and then if possible trace to their forerunners on the urodele or fish.

The rectus abdominis occupies the ventral surface of the abdomen. It extends from the pelvis to the thorax. If well cleaned it may be seen to be composed of four segments arranged in longitudinal series, suggesting a myotomic origin.

Refer to Plate I for aid in locating the following muscles:

Extending from the cephalic end of the sternum to the hyoid bone in the median line is the sterno-hyoid. Directly under it is the sterno-thyreoid, and lateral to it is the slender omo-hyoid extending from the shoulder to the hyoid. Extending from the hyoid to the symphysis of the mandible underneath the transverse mylo-hoid is the genio-hyoid. These muscles, viz: the rectus abdominis, sterno-hyoid, sterno-thyreoid, omo-hyoid and genio-hyoid constitute a series of segmented muscles extending from the pubes to the point of the chin interrupted only by the sternum.

On the lateral surfaces of the abdomen (Plate II) are the external obliques. Immediately underneath the external obliques are the internal obliques. The fibers of these two muscles run at right angles to each other. Underneath the internal obliques is the transversus muscle whose fibers run transversely. The three last mentioned muscles insert ventrally into layers of flat, tendinous tissue (aponeurosis) which meet in the mid-ventral line (linea alba). These muscles no longer retain a segmental character, excepting a small portion of the origin of the external oblique.

In the region of thorax, between the ribs are the external and internal intercostals. Their segmental arrangement is emphasized by the presence of the ribs. These muscles seem to be in series with the internal and external obliques. This series of lateral, segmental muscles is continued cephalad into the neck as several separate slips. One prominent neck muscle of the series is the scalenus. It is an important muscle lying on

PLATE I. Dissection of head, neck and thorax of dog, ventral view. 1, mylo-hyoid; 2, genio-hyoid; 3, orbicularis oris; 4, anterior facial vein; 5, parotid gland; 6, posterior facial vein; 7, sublingual gland; 8, sub-maxillary gland; 9, anastomotic branch of facial veins; 10, trachea; 11, sterno-hyoid; 12, external jugular vein; 13, sterno-mastoid; 14, cephalohumeral; 15, pectoralis major; 16, pectoralis minor; 17, external jugular vein; 18, transverse scapular; 19, internal jugular; 20, cephalic vein; 21, cephalic vein; 22, subclavian (axillary) vein.

the latero-ventral region of the neck and upper thorax. Its origin is the lateral surfaces of the ribs under the scapula, whence it passes craniad to be inserted into the cervical vertebrae.

The muscles of the eye, six in number, arose from three head myotomes. Dissect these muscles from the front and identify them. (K. 133.) Do not remove the eye during the dissection, but the bones composing the orbit may be dissected away. Finally remove the eyes and after cutting away a tangential section from each to facilitate the penetration of preserving fluids preserve them in ten percent formaldehyde for future study.

The study of the axial muscles of the back should be postponed at this stage in order to investigate the appendicular muscles which have developed in mammals and birds to such an extent as to overlie and obscure much of the axial musculature.

Appendicular muscles are classified as extrinsic if they originate in the axis of the body and insert in the appendages. They are intrinsic if they lie wholly within the appendages. On the back of a urodele in the region of the shoulder find four muscles extending from about the mid-line of the back to the upper arm. These four beginning with the most cephalad are (1) the omo-hyoid, (2) trapezius, (3) dorsalis scapulae, (4) latissimus dorsi. Are these intrinsic or extrinsic muscles? In the dog the trapezius and latissimus dorsi will be easily recognized by their corresponding position. The anterior edge of the trapezius has sent its fibers far down the front leg and is called the cervico-humeral. Still another slip has come off the front edge of the cervico-humeral. It extends from the sternum to the mastoid

PLATE 2. Muscle dissection of dog. 1, orbicularis oris; 2, orbicularis oculi; 3, temporalis; 4, cephalohumeral; 5, scalenus; 6, levator scapulae ventralis; 7, trapezius cervicalis; 8, spinodeltoid; 9, triceps brachialis, medial head; 10, trapezius dorsalis; 11, latissimus dorsi; 12, intercostals; 13, sacrospinalis; 14, longissimus dorsi; 15, iliocostalis; 16, transversalis; 17, internal oblique; 18, quadriceps femoris, medial head; 19, gluteus medius; 20, gluteus maximus; 21, extensor caudi; 22, biceps femoris; 23, semimembranosus; 24, soleus; 25, extensor digitorum longus; 26, peroneus longus; 27, peroneus brevis; 28, tibialis anticus; 29, gastrocnemius; 30, quadriceps femoris, lateral head; 31, external oblique; 32, extensor indicis proprius; 33, flexor carpi ulnaris; 34, extensor carpi ulnaris; 35, extensor digitorum lateralis; 36, extensor carpi radialis longus; 37, extensor digitorum communis; 38, brachioradialis; 39, triceps humeralis, lateral head; 40, cephalohumeral; 41, acromiodeltoid; 42, external jugular vein; 43, sterno-hyoid; 44, sublingual gland; 45, submaxillary gland; 46, anterior facial vein; 47, parotid gland; 48, masseter; 49, parotid duct.

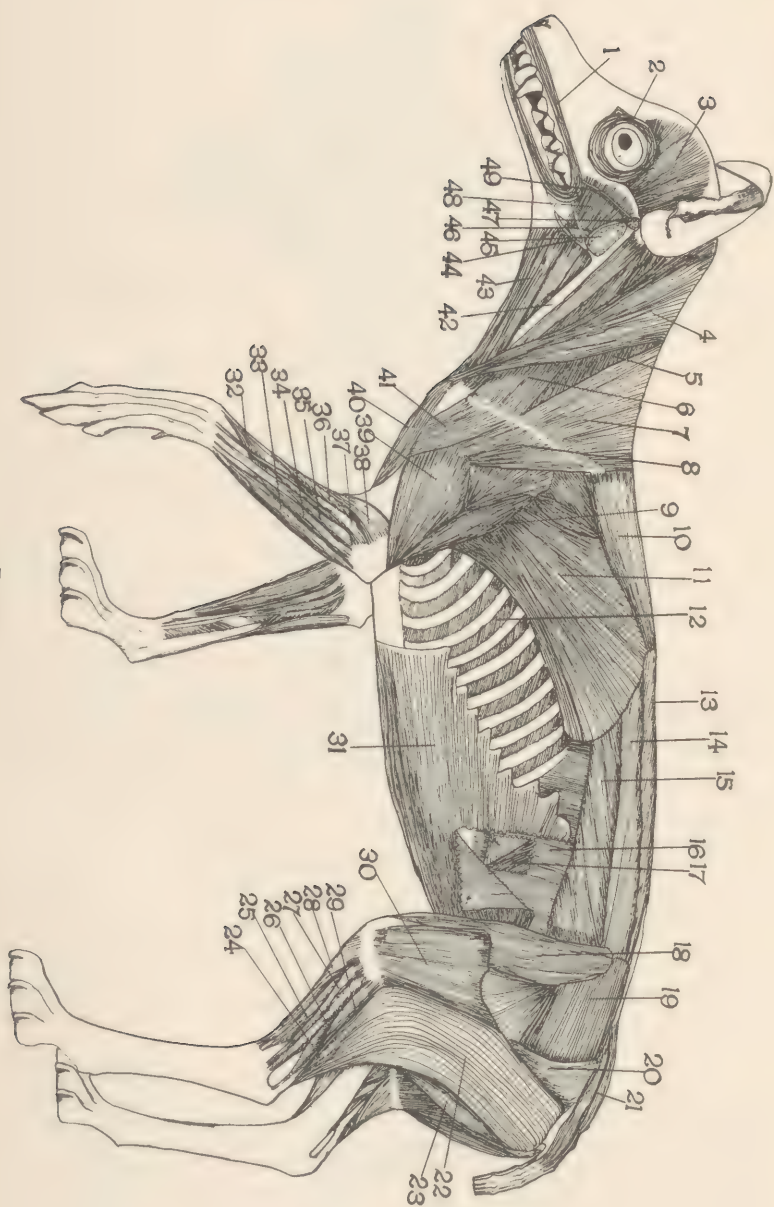


PLATE 2.

process behind the ear and is called the sterno mastoid. Also from the anterior edge of the latissimus dorsi has split off a secondary muscle which extends from the posterior border of the scapula to the humerus. It is the teres major. The dorsalis scapulae of the urodele corresponds to the supra spinatus and infra spinatus muscles of the dog, which lie in the supra spinous and infra spinous fossae respectively. These two muscles originate in the vertebral border of the scapula and insert into the upper portion of the humerus. The omo-hyoid seems to have fused with some other muscle in the dog, but it appears in human as a slender muscle extending from the shoulder (omo) to the hyoid bone.

Muscles of the Front Leg of Dog or Cat.

Plates I and II.

Spino-deltoid. On the lateral aspect of the shoulder, extends from the spine of the scapula to the upper end of the humerus.

Acromio-deltoid. Lateral aspect of the shoulder. It extends from the acromion process of the spine of the scapula to the upper end of the humerus.

Cervico-humeral. Previously mentioned. A broad thin muscle extending from the mid line of the neck down over the front of the arm to insert in the upper end of the ulna. It includes the following elements of human anatomy: the anterior portion of the trapezius, the cleido-mastoid and the medial head and fibers of the biceps brachii.

Rhomboideus. A rhomb shaped muscle extending from the vertebrae of the shoulder region to the scapula.

Rhomboideus capitis. A slender, ribbon-like muscle, evidently a slip from the rhomboideus. It passes from the superior angle of the scapula to the occipital. Also called the levator scapulae dorsalis.

PLATE 3. Muscle dissection of the medial side of the left arm. 1, trapezius; 2, rhomboideus; 3, serratus; 4, subscapularis; 5, cephalohumeral; 6, pectoralis minor; 7, pectoralis major; 8, biceps brachii; 9, brachial artery; 10, brachial vein; 11, extensor carpi radialis brevis; 12, extensor carpi radialis longus; 13, flexor carpi radialis; 14, flexor digitorum sublimis; 15, flexor digitorum profundus; 16, pronator quadratus; 17, latissimus dorsi; 18, teres major; 19, triceps humeralis, intermediate head; 20, 21, triceps humeralis, medial heads; 22, palmaris longus; 23, flexor carpi ulnaris.

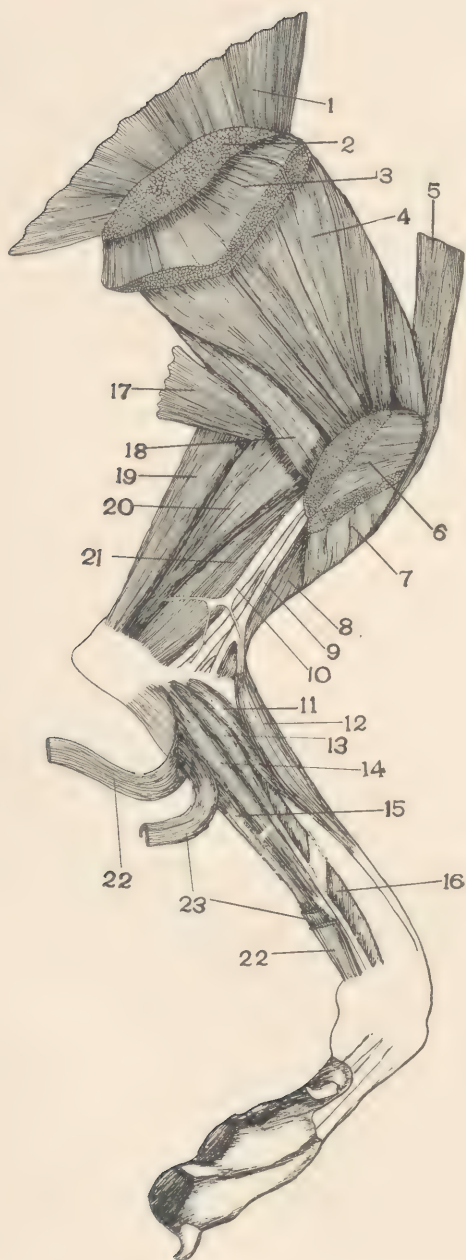


PLATE 3.

Levator scapulae. In front of the shoulder. It arises in the cervical vertebrae and extends to the superior angle of the scapula. It appears to be in series with the—

Serratus anterior. This muscle is underneath the scapula. It takes origin in the lateral surfaces of the ribs and inserts into the vertebral border of the scapula.

Levator scapulae ventralis. This muscle arises in the upper part of the neck, in the transverse processes of the upper cervical vertebrae and occipital. It extends to the lateral portions of the spine of the scapula.

Pectoralis major. A large, triangular muscle on the ventral surface of the thorax. It extends from a considerable portion of the mid-line of the thorax to the upper end of the humerus. It largely overlies the upper border of the—

Pectoralis minor. This muscle originates in the sternum caudal to the P. major and inserts into the upper end of the humerus.

Subscapularis. This muscle covers the entire surface of the under side of the scapula. (Plate III.) It inserts into the humerus.

Biceps brachii. Occupies the medial cranial surface of the upper arm. Its one head arises in the scapula. It inserts into the radius. The medial head of human anatomy has, in the dog, joined to the cervico-humeral.

Triceps brachii. Occupies the posterior surface of the upper arm. It is a stout muscle and is separable into three divisions known as the lateral, intermediate and medial heads. The intermediate head arises in the scapula. The other heads arise in the upper end of the humerus. All three parts unite and insert into the proximal end of the ulna (elbow).

Brachialis. This inconspicuous muscle is found on the lateral side of the upper arm between the biceps and the lateral head of the triceps. It originates in the humerus and inserts in the ulna near the elbow.

Brachio radialis. This is a long slender muscle. It arises in the lateral side of the humerus, crosses the elbow joint in front and inserts into the radius. It was formerly called the supinator longus.

Anconeus. A triangular muscle at the lateral side of the arm near the elbow. It extends from the distal portions of the humerus to the proximal portions of the ulna.

Extensors of the wrist and digits. These muscles are found on the antero-lateral aspect of the forearm, where by aid of the plate they may be dissected and identified. Commencing at the antero-medial border adjacent to the brachio radialis they are (1) extensor carpi radialis longus, (2) extensor digitorum communis, (3) extensor digitorum lateralis, (4) extensor carpi ulnaris, (5) extensor indicis proprius.

Flexors of the wrist and digits. These are found on the postero-medial surface of the forearm. They should be identified by the aid of Plate III and dissected. Beginning at the antero-medial border they are (1) flexor carpi radialis, (2) palmaris longus, (3) flexor carpi ulnaris. Under these is the (4) flexor digitorum sublimis whose tendons send divisions to each digit. On each digit each tendon is perforated by tendons from the (5) flexor digitorum profundus, a strong muscle lying underneath the other flexors. (6) The pronator quadratus is a small muscle lying between the distal ends of the radius and ulna. Its fibers run obliquely.

The tendons of these flexors pass along the wrist under a strong ligament known as the transverse ligament of the wrist.

Muscles of the Hind Leg of Dog or Cat.

Gluteus medius. A prominent muscle of the hip. It takes origin in the crest of the ilium and tapers to its insertion in the great trochanter of the femur. It is a stout muscle.

Gluteus maximus. This is a smaller, triangular muscle occupying the space between the gluteus medius and the root of the tail. It overlaps the gluteus medius. It arises in the sacrum and inserts in the femur.

Tensor fasciae latae. A short, triangular muscle anterior to the gluteus medius. It originates in the ilium and inserts into the broad fascia of the front and side of the thigh.

Quadriceps femoris. As its name implies it has four heads. They arise in the anterior crest of the ilium and upper extremity of the femur. This is the large, powerful extensor of the leg placed on the front of the thigh. If it is cut across with a clean

slash the four divisions can be easily seen. Its insertion is in the patella.

Biceps femoris. This the broad, flat muscle on the latero-posterior aspect of the thigh. It arises in the ischium and inserts into the upper, lateral portions of the tibia.

Semitendinosus. This muscle runs parallel with the biceps but inserts into the medial surface of the upper extremity of the femur. The large sciatic nerve cuts across the lower end of this muscle and comes between it and the biceps.

Semimembranosus. This muscle lies parallel and medial to the semitendinosus. Its origin and insertion are near those of the semitendinosus.

The last three mentioned muscles are flexors of the leg. Together they are called the hamstring muscles.

Adductores femoris. A set of strong muscles deeply placed on the postero-medial aspect of the thigh. They arise in the caudal portion of the pelvis and extend distally to insert throughout the length of the femur. What function is suggested by this name?

Sartorius. There are two long, flat, ribbon-like muscles on the medial surface of the thigh. The most anterior of these is the sartorius. It takes its origin in the ventral border of the ilium and inserts in the medial side of the upper extremity of the tibia.

Gracilis. This is the posterior of the two muscles which occupy the medial surface of the thigh. It is very thin in the dog and easily lost in removing fat. It inserts in the tibia posterior to the insertion of the sartorius. Its origin is in the posterior portion of the pelvis.

Ilio-psoas. A strong muscle mostly hid within the lumbar region of the body cavity. It emerges in the region of the groin and inserts in the lesser trochanter, a protuberance on the upper extremity of the femur. Its origin is twofold: (1) In the vertebrae of the lumbar region and (2) in the crest of the ilium within the pelvis. Look for it in the groin.

Gastrocnemius. This is the large flexor of the lower leg. It is commonly called the calf muscle. It arises in the lower end of the femur and inserts through the tendon of Achilles into the lower surface of the foot.

Plantaris. This muscle lies immediately underneath the gastrocnemius and uses the same tendon of Achilles for its insertion into the "heel." Its origin in the upper extremity of the fibula and patella may be seen between the two heads of the gastrocnemius.

Soleus. This muscle lies beneath and slightly lateral to the plantaris. It arises in the upper extremity of the fibula and joins its two fellows in the tendon of Achilles.

These three last mentioned muscles which are related to each other through the tendon of Achilles are powerful flexors of the foot, and together are called the triceps surae.

Popliteus. This is a small muscle found underneath the upper end of the soleus and plantaris. Its fibers run obliquely. Look for it on the under side of the knee joint.

Lying underneath the triceps surae are three flexors of the foot and digits. They are closely applied to the tibia and fibula and their tendons pass down over the medial side of the "heel" onto the sole. Beginning with the most lateral they are (1) the flexor hallucis longus lying behind the fibula, (2) the tibialis posterior behind the space between the fibula and tibia and (3) the flexor digitorum longus which lies behind the tibia.

Peroneus. On the lateral side of the leg are three peroneus muscles named beginning with the most anterior (1) peroneus longus, (2) peroneus brevis and (3) peroneus tertius. Their tendons pass over the lateral side of the ankle onto the sole or side of the foot.

Tibialis anterior. This muscle occupies the anterior surface of the tibia. It originates in the upper extremities of the tibia and fibula and inserts in the first or medial metatarsal.

Extensor digitorum longus. This muscle lies partly underneath and lateral to the tibialis anterior. Its origin goes up to the lower end of the femur. It inserts by means of four tendons into the digits.

Visceral Muscles.

Plates I and II.

These muscles occupy the lower part of the face, throat and larynx. They are all derivatives of the ventral portions of the head and neck myotomes. In fishes they are associated with the

gills, but in mammals they are mainly the muscles of mastication and the laryngeal muscles.

Mylo-hyoid. Previously mentioned. The thin, broad muscle whose fibers extend across the space from one side of the mandible to the other. It supports the floor of the mouth.

Masseter. A strong chewing muscle on the side of the head. It arises in the zygomatic arch near the eye and extends to the angle of the mandible. It is conspicuous on the outside of the jaw.

Temporalis. Another chewing muscle. It arises on the side of the head above and in front of the ear. Its fibers converge ventrally, pass under the zygomatic arch and insert into the coronoid process of the mandible.

Pterygoid. A pair of strong chewing muscles inside the jaw bones. They are most easily dissected from the ventral side of the jaws. They originate in the pterygoid processes of the skull and insert into the angles of the jaw.

Laryngeals. These are small, visceral muscles found inside the larynx. They control the vocal organs. Their dissection is not advised until the study of the respiratory system.

Diaphragm. This muscle seems to constitute a class by itself. It is the transverse, dome-shaped muscle inside the body cavity separating the thorax from the abdomen. It is used habitually in respiration.

Intrinsic Muscles of the Back.

The remainder of the axial system of muscles is yet to be examined. Prepare for this examination by detaching all the extrinsic muscles of the appendages at their proximal ends. The intrinsic muscles of the back present a complex of muscles in which separate, individual muscles are difficult to distinguish.

Extensor dorsi communis. This is the complex, superficial muscle of the back. It extends from the pelvic girdle to the ribs and dorsal vertebrae. As it passes anteriorly it can with some difficulty be seen to branch into three divisions, the most lateral of which is the—

Iliocostalis. As its name implies this muscle extends from the ilium to the ribs.

Longissimus dorsi. This muscle lies medial to the iliocostalis and extends from the ilium to the ribs. In the region of the neck and head this muscle has received the name of *longissimus cervicis* and *longissimus capitis*.

Sacrospinalis. This muscle is the most medial of the superficial muscles of the back. It extends from the sacrum to its manifold insertions into the spines of the vertebrae.

Transverso-spinalis. Underneath and somewhat medial to the sacrospinalis system is a system of muscles known collectively as the transverso-spinalis system. The fibers of these muscles are of varying length, but they all arise in transverse processes of the vertebrae and insert in spinous processes of anterior vertebrae.

Quadratus lumborum. This is a deep muscle on the dorso-lateral side of the abdomen. It arises in the crest of the ilium, passes cephalad and inserts into the last rib and intervening vertebrae.

Of all the muscles of mammals the intrinsic muscles of the back have preserved best their primitive myotomic arrangement.

DIGESTIVE SYSTEM.

The digestive system is that system of organs which (1) receives the food and (2) by macerating and dissolving it prepares it for assimilation into body tissues and (3) by a process of osmosis takes it up and passes in on to the circulatory system. This threefold function of the digestive system should be constantly kept in mind during the following study.

Development.

Examine slides of chick embryos of 50 to 70 hours incubation. First, for general relations, examine slides of the whole embryo, then examine slides of cross sections. Identify on the latter slides the endoderm which forms the lining of the entire digestive system including the extra embryonic yolk sac. (K. 381.)

In the anterior region the digestive tract is a tube opening posteriorly known as the fore gut. Similarly there is a tube formed in the posterior portion of the body and opening anteriorly known as the hind gut. That portion of the tube in the

middle region of the body still open ventrally to the yolk sac is designated as the mid-gut.

On the slide of sections trace the fore gut forward to the oral plate, which is a membrane separating the fore gut from the stomodeum. From your own observations decide what germ layers have entered into the formation of the oral plate. In the posterior end of the hind gut find the anal plate and proctodeum. For future reference make outline sketches of these structures.

Mouth.

What is the position of the mouth in sharks, sturgeons, teleosts, amphibians, birds, reptiles and mammals? What position may be regarded as the most primitive? Which of the above mentioned animals have movable lips? Why are lips essential to mammals?

Oral Glands.

Oral glands are found only in terrestrial animals. All aquatic forms, including the whale, lack oral glands. Explain.

In pit vipers a pair of oral glands have become specialized as poison glands. They may be discovered underneath the skin behind the eye as whitish, fibrous sacs. Their ducts may be traced to the roots of the fangs.

In dog three oral glands may be found in a row underneath the root of the ear. (Plate I and II.) They are the parotid, the submaxillary and the sublingual. A fourth pair of oral glands, the orbital, may be found in the floor of the orbit of the eye. Ducts convey saliva from all these glands to the mouth, and may be easily dissected. Describe the course of the parotid duct and the submaxillary duct. Observe the first three mentioned glands in human (manikin).

Teeth (K. 223).

The embryology of the teeth may best be studied by examining slides of a cross section through the jaw of a foetal pig. By reference to Figures 234 and 236 (K. 225, 226) the following parts of a developing tooth and surrounding tissues should be identified. Make a drawing. Epidermis, mesenchyme, jaw bone, dentine, pulp cavity, enamel organ, dental ridge.

Investigate the presence of and distribution of teeth in sharks, teleosts, amphibians, birds, reptiles and mammals. This investigation may involve examining the extreme posterior regions of the mouth of your specimens. Notice particularly any specialized teeth, such as fangs. Make a record of your findings. What in general is the origin of all vertebrate teeth? (See under Integument.)

Investigate the roots of the teeth of fish, amphibians and mammals to determine the character of the contact with the underlying bone. Which class or classes of vertebrates possess teeth with roots fitting into sockets? Classify the teeth of all the specimens of vertebrates provided you as to (1) succession. I. e., which specimens develop one set of teeth following another? (2) Method of attachment to the underlying bones. I. e., which specimens possess acrodont teeth, which possess pleurodont teeth and which possess thecodont teeth? (3) Variation in structure. I. e., which specimens are homodont and which are heterodont? (4) Structure. I. e., identify among your specimens any hypsodont, bunodont, secodont, solenodont or lophodont teeth.

Make outline sketches of the following types of teeth: placoid, fang, incisor, canine, premolar, molar, carnassial. Write the dental formula of dog and man.

In the museum examine and write the dental formulae of the following: bear, lion, tiger, seal, sloth, squirrel, horse, llama, tapir, deer, elephant, spider monkey.

What characteristics are common to the teeth of all carnivores? of all ungulates? of all rodents? of all primates?

Examine the microscopic structure of the tooth of a dog. For this purpose break the tooth out and grind the broken surface smooth on a grindstone, soak the tooth for about five minutes in methylene blue, rinse it in running water and view it by reflected light with the high power if possible. These structures should be distinguished. Enamel, or cement, if a root is being examined; dentine, pulp cavity. In the dentine are minute parallel dentinal canals.

Epidermal teeth may be observed in the buccal funnel of cyclostomes. These teeth are not homologous to the teeth of higher vertebrates. (K. 231.)

Tongue (K. 232).

Make observations on the presence of and general structure of the tongue in shark, teleost, amphibians, snakes, lizards, turtle, birds and mammals. The tongue is lobated, but the lobes are indistinct in mammals. In lizards three lobes can be easily distinguished. They are an anterior lobe and two posterior lobes.

Examine minutely the surface of the dog's tongue. It is covered with minute papillae, of which there are three types: (1) the conical papillae, which are most abundant; (2) fungi-form papillae placed about five millimeters from one another; they are rounded on top; (3) the circumvallate papillae. On the dog's tongue there are only three or four pairs lying in a V-shaped line with its apex directed posteriorly lying about two-thirds the length of the tongue from its tip. They are considerably larger than the other types of papillae.

Taste buds, the end organs of the sensory nerves of the tongue, are in the corium of the tongue most abundant on the sides of the papillae. (Microscopic slide.)

The foramen caecum, a minute depression claiming interest only as marking the point of origin of the thyroid gland, lies at the apex of the V formed by the circumvallate papillae.

The following extrinsic muscles of the tongue may be exposed and easily identified by their origin and insertion as indicated by their names: genio-glossus (chin to tongue); stylo-glossus (styloid process to tongue); hylo-glossus (hyoid to tongue).

To examine the intrinsic muscles cut the tongue in two planes, one plane transversely, the other vertico-longitudinal. Three sets of muscle fibers will be exposed by these sections. These fibers extend in three directions, vertically, transversely and longitudinally.

Examine the tongue of a fowl. Do the intrinsic muscles appear to be well developed?

Pharynx.

Open the pharynx of the dog or cat by lateral slits carried from the corners of the mouth backwards, and by cutting away the soft palate from the roof of the mouth. Observe that the

following seven openings lead forth from the pharynx: in front the buccal cavity; two posterior nares above leading to the nasal cavities; two small Eustachian tubes on the superior lateral surface leading to the middle cavity of the ear; the oesophagus leading to the stomach and the opening of the trachea and lungs known as the glottis. The latter is surmounted by a cartilaginous flap, the epiglottis.

With a bristle or soft wire probe the Eustachian tubes.

Compare the position of the glottis and the posterior nares in the lower vertebrates, frog, cryptobranchus, lizard, snake, birds.

Are you able to distinguish a line of demarcation between buccal cavity and pharynx in amphibians and lizards? Are there any posterior nares in fish?

Two pairs of tonsils should be looked for at this time. They are (1) the palatine tonsils which are situated at the isthmus of the fauces, i. e., the narrow passageway between the mouth and the pharynx. Two lateral pillars will be seen extending from the roof of the mouth to the base of the tongue. These are the pillars of the fauces and the palatine tonsils lie between these pillars. (2) The pharyngeal tonsils are in the roof of the nasal portion of the pharynx dorsal and posterior to the openings of the Eustachian tubes. Identify these tonsils in the human manikin. The palatine tonsils may be seen by students looking into one another's mouths. Also by use of a mirror.

Oesophagus.

Observe the length and distensibility of the oesophagus of a fish, frog and snake. What adaptation to feeding habits do you find?

Open the thorax of a dog or cat. Without damaging the heart or any of the larger blood vessels find the oesophagus dorsal to the heart and between the two large blood vessels, the aorta on the left and the vena cava on the right. For minute study remove a small section of the oesophagus. Does it possess a shiny, serous coat (visceral peritoneum)? Endeavor to remove the tough, fibrous covering of connective tissue (adventitia). Under the adventitia are two layers of muscle fibers designated as the longitudinal and the circular muscle layers.

Endeavor to separate them. Which layer is outermost? Can the innermost layer of the oesophagus (epithelium, mucosa) be separated from the muscle layers?

In a bird dissect out the oesophagus. Observe that the crop is merely a saccular enlargement of the oesophagus.

Stomach and Intestine.

In order to record your observations on the stomach and intestines of the various vertebrates studied it is advisable to develop sketches of the parts as the work advances.

In the shark the stomach consists of a large descending portion and a much smaller ascending portion. At the anterior end of the small or ascending portion two ducts, (1) the bile duct and (2) the pancreatic duct enter. This point where these ducts enter is commonly regarded as being in the first division of the intestine known as the duodenum. These ducts together with their glands, the liver, the gall bladder and the pancreas should be identified and sketched. From this point the intestine turns abruptly posteriorly and extends directly to the anus. Open the intestine by a longitudinal slit or cut it transversely to see the spiral valve. What do you judge to be the function of the spiral? The extreme posterior division of the intestine is called the cloaca. It is made use of by the urinary and reproductive systems. Also leading into the cloaca is the rectal gland. Does the rectal gland lie within or to one side of the mesentery? Is the intestine attached throughout its length by means of a dorsal mesentery to the dorsal body wall? Is there a ventral mesentery? Is there a mesentery between the stomach and the liver? What is meant by the expression, "cardiac end of the stomach"? "pyloric end"? "fundus"?

In teleosts the stomach is roughly similar to that of sharks. Most teleosts possess a number of tubular sacs attached to the pyloric end of the stomach called pyloric caecae. Look for them in the perch. Does the catfish possess them? Do these fish possess a spiral valve?

Examine the stomach of a urodele (*Amphiuma*, *Cryptobranchus* or *Necturus*). Is it straight or V-shaped? Are pyloric caecae present? Is a rectal gland present? Is there a dorsal mesentery present throughout the length of the small intestine?

Can the colon or large intestine be distinguished from the small intestine?

With a hand lens examine the inner surface of the stomach of a urodele for stomach pits. These are minute openings in the epithelium of the stomach. Are you able to find them in the lining of the intestine? The lining of the intestine is characterized by the presence of numerous minute, finger-like projections, resembling somewhat the nap of velvet. These are the villi. To see them cut out a small piece of the small intestine, wash it thoroughly in running water and view it with the low power while it is immersed in water.

Examine alternately prepared slides of transverse sections of the stomach and intestine of urodeles. Drawings should be made. Identify the following layers: (1) serosa, the outermost layer, an exceedingly thin membrane and easily overlooked; (2) subserosa, a thin layer of connective tissue underneath the serosa; (3) muscular layer. There are two layers of muscles the fibers of which run at right angles to each other. Determine which layer contains the longitudinal and which layer the circular muscle fibers. Underneath the muscular layer is a layer of connective tissue called (4) the submucosa. Below the submucosa is a second layer, very thin, of muscle fibers known as (5) mucous membrane or mucosa. It consists of columnar epithelium. The epithelium of the stomach is complicated by the presence of stomach glands connected to the stomach pits referred to above. In the intestine there are no pits or glands, but the villi are conspicuous, between which there are deep open spaces known as crypts. Goblet cells are also noticeable in the epithelium of the intestine.

How many folds in the digestive tract of snakes? Is this number of folds common to all species of snakes examined?

Has the bird a true stomach? Is the gizzard of birds homologous to the stomach of other vertebrates? (K. 240.) What kind of muscle tissue constitutes the wall of the gizzard? Find the proventriculus. The gizzard of birds compensates for the lack of what other organ in other vertebrates?

In dog or cat make a study of the omenta. These are delicate, filmy membranes with numerous meshes in which are lodged masses of fat. The great omentum is attached to the

greater curvature of the stomach and hangs forward over the intestines like an apron. The lesser omentum extends from the lesser curvature of the stomach to the liver. It consists of two layers closely applied to each other. The bile duct and portal vein are between these two layers. These two layers upon reaching the stomach separate, thus enclosing the stomach. Over the stomach the membrane is not a meshwork but a continuous layer and is called the visceral peritoneum of the stomach. The two peritoneal layers unite again at the greater curvature of the stomach and together form the anterior layer of the great omentum. After passing down in front of the intestine they fold back on themselves dorsally. Upon encountering the transverse colon they do not separate as they did at the stomach, but both pass ventrally over the colon and continue to the dorsal body wall. See Figure 2.

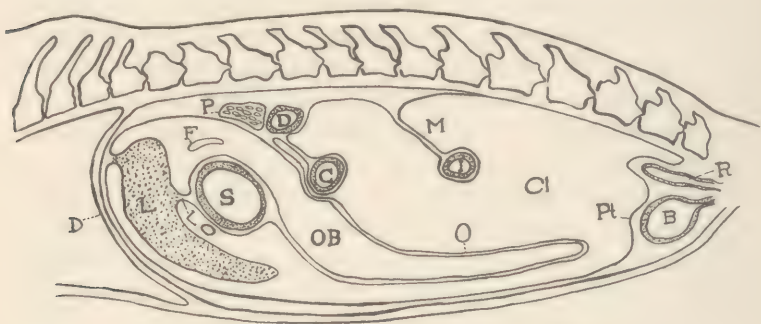


FIG. 2. Diagram of omenta and mesenteries of dog. D, diaphragm; L, liver; LO, lesser omentum; S, stomach; F, epiploic foramen; P, pancreas; D, duodenum; C, transverse colon; OB, omental bursa; O, great omentum; I, small intestine; M, mesentery; Cl, coelome; Pt, parietal peritoneum; B, bladder; R, rectum.

Embryologically the lesser omentum represents the ventral mesentery of the stomach, and the greater omentum represents the dorsal mesentery. It will be remembered that at one time in embryonic development the stomach occupied a lengthwise position in the body, then as the digestive tract increased in length more than did the body, the pyloric end of the stomach migrated over to the left side and the cardiac end moved to the right side. The dorsal wall of the stomach became the caudal side, or side of the greater curvature. This brought the dorsal

mesentery to a caudal position. The student can imitate this process with a book and a handkerchief.

The two omenta divide the abdominal cavity of mammals into two cavities: a larger cavity outside the omenta known as the greater abdominal cavity and a lesser cavity inside the omenta known as the lesser abdominal cavity or omental bursa. These two cavities are connected with each other by a foramen which may be found dorsal to the pyloric end of the stomach. Raise the stomach with the right hand and pass the fingers of the left hand through the narrow, slit-like opening. This foramen is known as the epiploic foramen. (K. 18.)

In the intestine of dog or cat distinguish the following divisions: duodenum, jejunum, ileum, colon and rectum. Three subdivisions of the colon should be recognized, ascending colon, transverse colon and descending colon.

Open and examine the two valves of the digestive tract: the pyloric valve which regulates the passage of food from the stomach into the duodenum and the ileo-colic valve which permits the passage of the contents of the small intestine into the colon but prevents its passage in the opposite direction. In examining the ileo-colic valve it was clear that the ileum entered the colon some distance from its terminus. That portion of the colon which lies caudal to the ileo-colic valve is known as the caecum. It terminates as a blind pouch. Examine the caecum of any rodent (squirrel or guinea pig). Has the dog a vermiform appendix attached to the caecum? Has the cat a vermiform appendix? Identify these parts on man (manikin).

Liver.

The liver is the largest gland in the body. It arose embryonically as an outgrowth from the duodenum. It consists of several lobes. How many lobes are there in the liver of the dog or cat? Partly concealed under one of the lobes of the right side is the gall bladder. In dog, cat and man the arrangement of the bile ducts should be understood. The bile ducts may be regarded as forming a T. One arm of the T arises in the liver and is known as the hepatic duct, the other arm connects with the bladder and is known as the cystic duct, the third branch or main stem of the T connects with the duodenum and is known

as the common bile duct. While most vertebrates possess a gall bladder, it is lacking in pigeon, horse, deer, rat and pocket gopher.

Examine prepared slides of the liver of a mammal. It is composed of a mass of many sided lobules. In the center of a lobule find the central vein. Leading centrally into the central vein are numerous sinusoids. Between the lobules are interlobular veins. Draw a lobule showing the above mentioned structures.

Pancreas.

This gland is found in all vertebrates in close relationship to the duodenum. It contains in mammals a main and an accessory duct. The accessory joins the main duct, which in turn enters the duodenum. Its opening in the duodenum may be found by opening the duodenal wall so as to expose the inner surface. Microscopically the pancreas consists of a mass of tubules surrounded by conical cells. In most slide preparations the forerunner of the pancreatic juice may be seen in the form of granules lying near the inner apex of the cells. This material in the pancreatic cells is called zymogen. Draw a cross section of a tubule.

Of considerable importance are the distinguishing characteristics of the microscopic structure of the major divisions of the digestive tract in mammals. These characteristics are herewith condensed and listed and should be verified from slides:

Oesophagus. Stratified epithelium; presence of mucous glands underneath the epithelium.

Stomach. Simple columnar epithelium; gastric pits are present from the bottoms of which lead off clusters of gastric glands with closed lumina.

Small intestine. Simple columnar epithelium cast into folds, which in turn are covered with villi; goblet cells are present.

Large intestine. Simple columnar epithelium; goblet cells are present; no villi.

RESPIRATORY SYSTEM.

(K. 252.)

Vertebrates are either water breathers (Ichthyopsida) possessing gills or air breathers (Sauropsida and mammals) possessing lungs.

What are the three classes of Ichthyopsida?

Gills.

Determine the number of gill slits in the cyclostome eel. Of which division of the digestive tract are the gills a part? How many gills has the shark? the stingaree? Find the spiracles in the shark (K. 254, 255). What is their apparent function? Do they seem to be in longitudinal series with the gill slits? Do all sharks have spiracles? Draw a cross section of a gill arch of a shark. Identify demibranch, septum, branchial ray, skin, blood vessel, cartilage (Figure 274, K. 255). What are the essential differences between the gills of a shark and those of a teleost? Define operculum.

Examine shark, perch and catfish for the presence and character of the swim bladder. Determine in these forms whether or not the swim bladder is attached by a duct or ligament to the digestive tract. Would any such connection between the swim bladder and the digestive tract suggest that the swim bladder is homologous to the lungs of Sauropsida and mammals?

Examine the gill of *Necturus*. Observe that the full quota of five (or four) gills is not present. Make a drawing of a cross section of a gill filament of *Necturus*. Identify and label skin, connective tissue, artery, vein. Is the covering of a gill filament ectodermal or endodermal? (Figure 271, K. 252.)

Do frogs and toads ever possess external gills?

Glottis and Larynx (K. 270).

Locate the glottis in frog, snake, fowl and dog. Can you explain why the glottis of the snake is so far forward in the mouth? Are snakes capable of producing vocal sounds?

The larynx of the dog may be removed for examination. Open the larynx with a ventral slit. Two pairs of tough, transverse shelves will be seen projecting towards the center of the

larynx. These are the "vocal cords." The uppermost pair are the false cords because they are not directly used in producing sound. The "vocal cords" proper are the true sound producers. The false cords, the pharynx, the nasal cavity, the tongue, lips and cranial sinuses aid in modifying the sound. Numerous muscles will be seen within the wall of the larynx which contract and relax the cords and modify the character of the laryngeal cavity. These muscles are collectively known as the laryngeal muscles.

The cartilages of the larynx should be dissected apart and identified. The uppermost cartilage which acts as a trap door to cover the opening into the larynx is the epiglottis. The shield-shaped cartilages in front are the thyroid cartilages. These in man are the commonly called Adam's apple. Dorsal to the thyroid cartilages are the arytenoid cartilages. Most caudal of all is the circular cricoid cartilage. These cartilages are believed to have originated as modifications of the cartilages of the gill arches.

Examine the trachea of dog or cat. Are the cartilaginous "rings" complete rings? Can the trachea ever collapse?

In fowls the larynx is replaced by the syrinx, a vocal organ similar to the larynx but placed in the thorax at the bifurcation of the trachea into the bronchi. Examine the syrinx in pigeon.

Nasal Cavity.

With bone forceps open the nasal cavities of dog or cat. The two cavities are separated from each other by a nasal septum which is composed of the vomer bone covered with a thin layer of connective tissue and epithelium. Extending into the cavities from the sides are the turbinates. These are spiral, spongy masses of bone covered with thin connective tissue and epithelium. The most dorsal turbinates are covered with olfactory epithelium. In the dog and bear this olfactory epithelium is much more abundant than in most other mammals.

Thyroid Gland.

(Most conveniently studied here although not a part of the respiratory system).

The thyroid gland in dog and cat lies at the base of the neck applied to the ventral side of the trachea. It consists

usually of two lobes lying one each side of the trachea with a transverse process between the two. Having no duct it is classified as a ductless gland or endocrine gland. Is it well supplied with blood vessels? Examine a prepared slide of the thyroid gland. It consists of a mass of spherical alveoli each of which possesses epithelial walls and a cavity filled with a gelatinous colloid. For a record of the structure of the thyroid a drawing should be made of a few alveoli.

Lung (K. 275).

Are there paired lungs in frog, snake, dog?

From a recently killed dog or cat remove an entire lung together with its bronchus attached. By means of a glass tube inflate the lung, noting the amount of expansion. When the air pressure is released does the lung collapse? Do you consider from this experiment that the lung contains elastic tissue? If in dog or cat the cavity around the lungs (pleural cavity) be punctured so as to allow air to enter the cavity but not the lung, would the lung collapse from its own elasticity? Would a dog or cat be able to inflate a lung whose pleural cavity was thus opened? How is inhalation accomplished in mammals? How is exhalation accomplished?

Examine the pleurae or thin membrane lining the cavity from which the lung was removed. Where was it attached to the lung? This pleura is called the parietal pleura to distinguish it from the visceral pleura which immediately covers the lungs.

Cut a slice from a preserved lung and examine its porous character and numerous air sacs. These air sacs are lined with a delicate epithelium continuous with the epithelium of the trachea and pharynx. What germ layer is this lining?

UROGENITAL SYSTEM.

(K. 334 ffg.)

The urine excretory system and the reproductive system are so intimately connected with each other in all vertebrates that it is expedient to study them together, but as far as possible attention will be directed first to the urinary system. The urinary system in all vertebrates consists of (1) a pair of glands

commonly called kidneys, whose service is to extract nitrogenous waste from the blood. This nitrogenous waste is conveyed in liquid form through (2) a pair of uriniferous ducts called ureters to (3) the bladder, if present, thence through the (4) urethra to the outside.

Among the chordates there are three types of excretory systems known as the pronephros, the mesonephros and the metanephros.

Pronephros.

The pronephros is found in *Amphioxus*, ascidians, Enteropneustes and the embryos of all vertebrates. Examine the slide of a chick embryo of 38 hours incubation (16 somites). For details and description of the pronephros recourse must be had to the text (K. 337 ffg.).

In general the pronephros consists of a series of tubules and a single duct. The tubules are distributed one to a somite usually in the anterior portions of the embryo. One end of each tubule opens into the coelome. This opening is called the nephrostome. From the nephrostome the tubule pursues a tortuous course to the pronephric duct. The duct extends posteriorly to the cloaca. It should be noted that there are no blood capillaries associated with the tubules. The nitrogenous waste in this case is eliminated from the blood into the coelome, whence it is drained through the nephrostomes through the pronephric system to the cloaca.

Mesonephros (K. 340).

This organ is the successor to the pronephros. It is found in the embryos of all vertebrates, persisting through life in all fish and amphibians and lingers a few days after birth in some lizards and primitive animals. See Fig. 1.

Find in a urodele the pair of long, slender, dark colored mesonephroi lying close together in the body cavity along the mid-dorsal line. Are they behind the peritoneum? (retroperitoneal). From their caudal ends trace the ureters posteriorly. Note that they enlarge to form the single bladder whence the urethra leads off posteriorly to the outside. This orifice is usually marked by a small urinary papilla. What is its position in relation to the anus? Make a sketch of the urinary system.

Examine a slide of a cross section of the mesonephros of *Amphiuma*. Two drawings will be required, (1) a drawing of the entire cross section and (2) a detailed drawing of a mesonephric corpuscle. The first drawing should show the general arrangement of the mesonephros, the position of the mesonephric corpuscles, Bowman's capsules, the mesonephric tubules and the mesonephric duct. Compare the stereogram (K. 342). The second drawing should show the coiled capillary within the glomerulus. By means of the differentially stained blood corpuscles the capillary tubes can be distinguished from the connective tissue.

Metanephros, Urinary Passages, Bladder.

The metanephroi are the final (definitive) kidneys in all reptiles, birds and mammals. They are paired structures, lying high in the lumbar region, retroperitoneal, each side of the vertebral column. In reptiles, birds and most mammals the kidneys are lobated, but in some few mammals they are compact with smooth surfaces. What condition do you find in the dog or cat? In man (manikin)?

The mammalian kidney is commonly described as bean-shaped. At its hilus enter and leave the renal blood vessels and also from here leaves the ureter which conveys urine to the bladder. Find these structures in the dog and manikin. Ascertain which side of the bladder receives the ureters. Open the bladder and find the openings of the ureters. How far apart are they?

From the bladder urine is conveyed to the exterior through the urethra. In the female dog the urethra is relatively short and straight. It terminates by uniting with the reproductive passageway (vagina) near the orifice of the latter to form the urogenital sinus. By means of bone forceps cut away the bones forming the floor of the pelvis and dissect these structures. If the urethra be slit open throughout its entire length it may be more easily traced.

In the male dog or cat the urethra receives near its origin the two spermatic ducts. The entrance of these ducts into the urethra may be exposed by slitting open the urethra for some distance along the inner end. The glandular mass encircling

the urethra at the point where the spermatic ducts enter is the prostate gland. A pair of glands, known as the bulbourethral glands lie either side of the urethra about an inch from the prostate. The bulbourethral gland is surrounded with muscles. Since the urethra of the male must traverse the penis it is somewhat longer than in the female. In which portion of the penis, dorsal or ventral, does the urethra lie? Is there a bone in the penis of the dog? Of the cat?

Make sketches of the urinary system of both sexes. Preserve these drawings with a view of adding the reproductive system.

Detail of Kidney.

Remove a kidney from the dog or cat. The adrenal gland will be found fitting like a cap on the antero medial end of the kidney. Remove and preserve the adrenal gland for future study.

Clean away any fat around the hilus of the kidney. Note that the upper end of the ureter upon passing into the kidney spreads out into a funnel-like structure known as the pelvis of the kidney. For a better view of the pelvis split the kidney longitudinally through the hilus. It can then be seen that the pelvis is a closed sac into which project the apexes of numerous cones or pyramids. These pyramids do not actually penetrate the epithelium of the pelvis but project into the space of the pelvis, pushing the epithelium before them.

A sketch of the longitudinal section of the kidney should be begun at this time. All the above mentioned structures should be shown and other structures added as they are studied.

In the smooth, cut surface of the kidney two areas of different character can be distinguished: (1) the cortex which is the outer layer, and (2) the medulla or inner layer.

The cortex contains minute, dark spots which can be seen with the unaided eye or better with a lens. These dark spots are the renal corpuscles. They are similar in structure to the mesonephric corpuscles but smaller. In the medulla are numerous striations which are the renal tubules or uriniferous tubules. They arise at the renal corpuscles, pursue a rather tortuous course in the cortex, dipping once deeply down into the medulla (loops of Henle) and finally terminate at the apexes of the

pyramids, where they pour their excretion through minute openings (papillary foramina) into the pelvis of the kidney. From here, as described above, the excretion is conveyed away through the ureters, etc.

A comparative study of the mesonephros and metanephros will be made from slide preparations of the pig embryo. Fortunately in the pig embryo of about 26 millimeters length the metanephros appears before the mesonephros atrophies, so that the two types of nephroi appear side by side. Furthermore the mesonephros is unusually well developed in pig embryos and is doubtless functional.

From your study of the slides and from other sources compare the mesonephros and the metanephros according to the following:

- (a) Order of appearance in the embryo.
- (b) Presence of a hilus.
- (c) Presence of a cortex and medulla.
- (d) Location of the glomeruli, whether in the cortex or near the hilus.
- (e) Relative number of glomeruli.
- (f) Relative size of glomeruli and Bowman's capsules.
- (g) Relative size of uriniferous tubules.
- (h) Character of the contour of the tubules. Are Henle's loops present?
- (i) Do the tubules receive tributaries?

Adrenal Gland.

(Most conveniently studied here although not a part of the urinary system).

The shape of the adrenal glands is irregular, determined apparently by the pressure of surrounding organs. Having no duct it is classed as an endocrine gland. Its blood supply is abundant.

With a clean slash cut the gland in two. The cut surface shows two well defined areas: (1) an outer, grayish area known as the cortex, and (2) an inner, darker area known as the medulla. Microscopic examination of the adrenal reveals the cortex as composed of columns of cells perpendicular to the surface, the cells of which contain much fat in the form of

vacuoles. The medulla contains dark colored cells known as chromaffin cells. These are believed to be the source of adrenalin, the hormone which is known to effect blood pressure and exert a control over muscle tonus.

REPRODUCTIVE SYSTEM.

(K. 346.)

The essential functions of the reproductive system are: (1) to produce germ cells, (2) to provide for the escape and union of these germ cells (fertilization), and in some forms (3) to provide a receptacle to receive, protect and nourish the young embryo.

The glands which produce the germ cells are collectively called the gonads. The remainder of the reproductive organs are the internal genitalia and the external genitalia.

Shark and Urodele—Male.

In the shark the male can be distinguished by the presence of a pair of claspers attached to the anal fins. Do you consider the claspers as a modified portion of the fins? There seem to be no external sex differences in urodeles.

Within the abdominal cavity of a shark or urodele find the slender, elongate, paired testes ventral to the kidneys and ranging towards the caudal end of the cavity. Observe that they are attached to the body wall by a fold of mesentery (mesorchium).

Extending from the testes to the kidneys are numerous minute ducts, the vasa efferentia, through which the male germ cells are conveyed from the testes. These vasa efferentia discharge their contents into the uriniferous duct of the mesonephros. This duct, therefore, serves the double purpose of carrying away the products of both the testes and the kidneys. Determine the location of the orifice of each duct. Are the orifices within the cloaca or external?

The mature male germ cell is called a spermatozoon. To see whole spermatozoa remove a small section from the caudal tip of a testis of a urodele. Thoroughly tease this particle, stain with acid fuchsin or methylene blue, remove the excess stain and apply a cover glass or permit the preparation to dry. Each

sperm consists of a head, a constricted middle and a tail which in life is vibratile. By means of this vibratile tail the sperm is able to accomplish locomotion.

Shark and Urodele—Female.

In the mature shark and urodele the ovaries are large, elongate bodies in the posterior region of the abdominal cavity. The oviducts are long, much convoluted tubes extending throughout the abdominal cavity. The anterior openings of the oviducts is nearly as far forward as the level of the heart or the anterior terminus of the lungs. The openings are known as the ostia tubae. The posterior portions of the tubes may be dilated to form paired uteri. The uteri in turn may open into the cloaca or to the outside according to the species under examination. Trace the entire passageway in your specimen. Are the oviducts united anteriorly or posteriorly?

It will be observed that there is no connection between the ovaries and the oviducts. Trace the course of an ovum after it leaves the ovary until it emerges from the body. Make a list of those vertebrates in which the ovaries are saccular and connected to the oviducts (K. 351, 359). Examine the ovary of a marine catfish. What type of ovary has it?

Examine slides of the ovary of a urodele. Are the developing ova (oöcytes) abundantly supplied with yolk? Is the nucleus central? Are chromosomes visible? A drawing should be made.

Make a drawing from slide preparations of a cross section of the oviduct of urodele. Do the folds in the wall of the oviduct suggest that it is capable of considerable expansion? What is the necessity for such an arrangement? What type of epithelium forms the lining of the tube? What is the embryological derivation of the oviduct in shark, teleost, urodele? (K. 351.)

Sauropsida.

Determine the shape of the testes and ovaries in snakes. Are the testes and ovaries paired or single in snakes? Are the ovaries and testes paired in pigeon? Find the shell gland in pigeon at the posterior end of the oviduct. From its name and position what would you judge to be its function?

Mammal—Male.

Embryologically the testes originated in close relation to the mesonephroi behind the peritoneum. In most mammals the testes migrated posteriorly from that position into the pelvis. In many mammals the migration continued from here along the inside of the lateral walls of the pelvis until the testes passed ventral to the pelvic bones and became lodged in a sac (scrotum). The scrotum, though outside the body cavity, contains an extension of the body cavity. In making its descent each testis carried along with it two layers of peritoneum known as the tunica vaginalis. The layer lying upon the testis and practically inseparable from it is the visceral layer. The outermost layer is the parietal layer. Between these two layers there is a space.

Make a list of those mammals in which the testes do not descend and those mammals in which the testes do descend. (K. 373.)

Open the scrotum of a dog or cat and examine the tunica vaginalis and the testes. Cut off a tangential section of a testis. Observe that it is divided into lobules. With a dissecting needle the small white seminiferous tubules may be lifted out of the lobules. These tubules contain the developing spermatozoa.

Examine slide preparations of testes in which the tubules will for the most part appear in cross section. Within each tubule will be seen the sperm cells in nearly all stages of development. Applied to the basement membrane within the tubules are the most primitive of the developing germ cells, viz: the spermatogonia. Central to these are two or three layers of cells with large, loose nuclei, the spermatocytes, and central to these are the spermatids which may be recognized by their compactness and avidity for stain. In the lumina of the tubules may be seen fully developed spermatozoa which may occur as bundles of parallel whip-like structures, usually heavily stained. The spermatozoa are on their journey through the tubules out of the testis.

Draw a cross section of a tubule showing the four stages of development of the spermatozoa.

The spermatozoa make their escape from the testis through small tubes known as the vasa efferentia. These tubes lead into

the epididymis, which may be found in dog as a mass of tissue attached to the median side of the testis. Microscopic examination of this mass shows that it is composed of small ducts, all of which ultimately unite into one common duct, the vas deferens. The vasa deferentia pass from the scrotum into the pelvic cavity ventral to the pelvic bones: that is to say by the same route which the testis took in its descent. The vasa deferentia course through the pelvic cavity and terminate by joining the urethra in its prostatic portion, as described under the urinary system. Branching out from each vas deferens as it passes through the prostate gland is a sac known as the seminal vesicle which receives and stores up a supply of spermatozoa.

The lower portions of the vas is muscular and capable of forcibly ejecting the spermatie fluid (ejaculatory duct).

Mammal—Female.

If the vagina of the dog or cat has not already been examined in connection with the study of the urinary system it should now be slit open throughout its entire length (bone forceps) and the mouth or os of the uterus exposed. The os is ordinarily kept closed by the sphincter muscle in the wall of the cervix, or neck, of the uterus.

The uterus in dog and cat is Y-shaped (bicornis). Attached to the tips of the horns of the uterus are the short oviducts, more properly called the uterine tubes (Fallopian tubes). At the extremities of these tubes are the ovaries encased in capsules. Open the uterus and carefully examine it inside for the presence of any small embryos.

Examine the surface of an ovary for the presence of any whitish scars (corpora lutea) made by the rupture of the ovary by the discharge of an ovum.

Examine microscopic slides of a mammalian ovary. The developing ovum lies in a follicle in which, besides the ovum, are numerous small epithelial cells. After the ovum is discharged the follicle fills immediately with blood (corpus hemorrhagicum). The blood is later displaced by large, fat laden cells (corpus luteum) which are ultimately replaced by white fibrous connective tissue (corpus albicans).

Drawings of the reproductive systems of both sexes should now be added to the drawings previously required of the

urinary system. Note the interlocking of the ureters with the vasa deferentia. Show how this was accomplished by the descent of the testes.

CIRCULATORY SYSTEM.

(K. 285.)

The circulatory system consists of (1) blood and lymph, the circulating fluids; (2) a heart, an organ which propels the blood; (3) arteries, vessels which convey the blood from the heart; (4) veins, which convey the blood to the heart, and (5) capillaries, minute blood vessels connecting the arteries and veins at their distal terminals.

The function of the circulatory system is (1) to collect food at the digestive tract and distribute it throughout the body; (2) to collect oxygen at the gills or lungs and distribute it throughout the body; (3) to collect waste substances from all parts of the body and carry them to those organs which eliminate such waste, and finally (4) to collect hormones from the endocrine glands and carry them to those organs which will be activated by those hormones.

Elasmobranchs and Teleosts.

Heart.

Find the heart of a shark or teleost. It is placed well forward, close to the lower jaw. Blood passes forward through a series of four chambers. These four chambers, beginning with the most posterior, are (1) sinus venosus, a thin walled structure, which receives the veins from the body; (2) the atrium, also thin walled, which acts as a reservoir; (3) the ventricle, a thick walled muscular structure; (4) the bulbus arteriosus, a cone-shaped vessel terminating in the ventral aorta. These four chambers, though in series, are not in a direct line.

Is the atrium dorsal or ventral to the ventricle? Is the sinus venosus dorsal or ventral to the atrium? Leading into the sinus are three large vessels: (1) the hepatic sinus, a short sinus in the mid-line extending from the liver to the sinus venosus; (2) the paired ducts of Cuvier which enter the sinus from each side.

Judging entirely from the structure of the walls of the heart which section is the main pumping organ of the heart?

Arteries.

Leading forward from the bulbus arteriosus is the ventral aorta. It extends toward the tip of the jaw. It distributes blood to the gills.

The anatomy of these distributing branches (afferent branchial arteries) should be determined by dissection of a shark, stingaree or teleost. Dissection is best accomplished from the ventral surface of the jaw. Remove the skin and muscle until the arteries and their branches are well exposed.

Draw the heart, ventral aorta and afferent branchial arteries.

Blood is collected from the gill capillaries and borne away by the efferent branchial arteries. These arteries will be found in the roof of the pharynx, dorsal to the gill arches. These arteries converge and unite to form the dorsal aorta. The arrangement of the efferent branchial arteries should be ascertained by dissection. Two branches are given off from the efferent branchials. They are (1) the carotid arteries, which pass from the first branchial forward into the head and (2) the coronary, a small twig which recurves from the last branchial through the last gill arch, making its way to the wall of the heart.

The dorsal aorta, as it passes down the back embedded in the vertebral column, gives off the following branches which should be dissected and drawn. Dissection of any one type of fish should be sufficient to demonstrate the dorsal aorta and its branches.

Subclavians (paired). These arise close to the union of the efferent branchials, sometimes from the last branchial, and pass to the pectoral fins. They are small in most teleosts, but should be large in the stingarees because of the enormous development of the pectoral fins.

Coeliac axis (single). This supplies the stomach and the duodenum.

Superior mesenteric (single). This supplies the lower portion of the intestine and the rectum.

Genital arteries (paired). In the female these arteries would be called the ovarian arteries; in the male they would be the spermaties.

Renal arteries (paired). These may consist of several small twigs to the mesonephros.

Inferior mesenteric (single). This is a small artery supplying mainly the rectal gland.

Iliacs (paired). These are branches to the pelvic fins.

Caudal artery (single). This passes to the tail and represents the continuation of the dorsal aorta.

Somatic branches (paired). These are given off at each vertebra and supply the muscles of the body wall.

Veins (K. 307 ffg.).

The ducts of Cuvier were mentioned above as conveying blood into the sinus venosus from each side. Emptying into the ducts of Cuvier on each side are four veins which should be found and traced well towards their source. They are (1) the jugulars arising in the head; (2) the subclavians which drain blood from the pectoral fins; (3) the post-cardinals which are the largest veins to enter the ducts; they arise near the kidneys and convey the purified blood from the kidneys back into the circulation; (4) the lateral veins; these arise in the pelvic fins, pass forward in the body wall, receiving many somatic tributaries and join the ducts near the subclavians.

The hepatic portal vein collects blood from the intestine and stomach and conveys it to the liver. In the liver the blood is distributed through a system of minute capillaries known as sinusoids. (Review under Liver.) These sinusoids should be viewed on a slide preparation of liver tissue which has been injected. Blood is collected from the liver by the hepatic sinus and carried to the sinus venosus.

Blood is collected from the tail by the caudal vein. Upon arriving at the abdominal cavity the caudal vein bifurcates into the two renal portal veins which carry blood to the mesonephros.

Draw the venous system.

How many capillaries must a given drop of blood pass in completing the circuit from heart back to heart?

Urodele.

By dissection determine the number of branchial arteries in a urodele. All amphibians possess lungs, therefore they must

possess a circulation involving these organs. Find the pulmonary circulation. From which branchial arch, if any, is it a derivative? The remainder of the arterial system is very similar to that of the fish.

There are no lateral veins in amphibians. The iliaes unite in the mid-ventral line to form an abdominal vein which courses forward to join the hepatic portal, but each iliac sends out a twig which anastomoses with the renal portal (Fig. 332, K. 312). Also in urodeles, as in all amphibians, there is a post-cava which arises between the mesonephroi; it passes forward to join the sinus venosus. It may pass through the liver, but it sends no branches into its tissue.

Make sketches of the arterial system and the venous system of a urodele.

Mammal.

Heart.

Before removing the heart of the dog or cat from its pericardium the blood vessels leading in and out should be identified. They are:

Aortic arch, the large vessel which arches dorsally and to the left of the heart. It continues down the back as the dorsal aorta.

Pulmonary arteries. The common pulmonary artery arises from the right ventricle near the aortic arch. It promptly bifurcates and each division divides into other branches which pass to the lungs. Look for the pulmonary artery under the aortic arch.

Superior vena cava. This large vein from the neck drains practically all the blood from the head into the right atrium.

Inferior vena cava. This large vein from the abdomen enters the posterior side of the right atrium.

Pulmonary veins. There are several of these carrying blood from the lungs to the left atrium. Just before entering the atrium they unite into three pocket-like extensions of the atrium.

These vessels may now be severed and the heart removed for further study.

Observe that the heart is cone-shaped with the apex directed caudally and to the left. The blood vessels enter and leave

through the base. The two membranous atria may easily be distinguished. Open the right atrium. Observe the tricuspid valve. It may admit the tip of the little finger. Observe the fossa ovalis, a depression in the median wall of the atrium. The floor of the fossa ovalis is the inter atrial septum, a thin membrane separating the right from the left atrium. This septum was of considerable importance embryologically. It was a valve which remained open during the embryonic period, admitting the blood from the right to the left atrium; this opening was known as the foramen ovale. At birth the valve closed the foramen thus forcing all blood entering the right atrium to pass through the tricuspid valve into the right ventricle.

By means of incisions directed from the apex to the base, open the two ventricles. The left atrium may also be opened.

In the right and left ventricles will be seen the ventricular sides of the tricuspid and mitral valves respectively. The flaps of the valves are not always individually distinguishable, but as a rule the tricuspid reveals three flaps and the mitral valve two. Chordae tendinae are the white, fibrous cords extending from the free edges of the valves to the apical ends of the ventricles. There they are attached to the summits of small, muscular projections known as muscular papillae. The function of the chordae tendinae is very evidently to prevent the valves being forced back into the atria at each contraction of the ventricles. The muscular papillae shorten at the time of ventricular contraction thereby compensating for the shortening of the ventricular cavity.

Which ventricle is the larger? Compare the ventricles as to shape. Compare the burdens of the two ventricles.

In the left atrium observe the atrial side of the mitral valve. How many cusps has it?

At the entrance of the aortic arch find the aortic valve composed of three cusps. Similarly at the entrance of the pulmonary artery find the pulmonary valve. Their operation in preventing any back flow of blood can readily be understood from their structure.

Arteries.

Blood leaves the heart of mammals by two entirely separate systems, (1) the pulmonary circulation and (2) the systemic

circulation. The pulmonary circulation has been previously observed, and since it consists of short arteries passing directly to the lungs, no further work on this system will be required. Do the pulmonary arteries carry blood rich or poor in oxygen?

The aorta is the main axis of the systemic circulation. It arises from the left ventricle, passes cephalad (ascending aorta), arches dorsally and to the left (aortic arch) and finally passes down the back slightly to the left of the mid-line (descending aorta). What muscular structure does the descending aorta penetrate? The portion of the aorta in the thoracic cavity is commonly designated as the thoracic aorta while the portion in the abdomen is the abdominal aorta.

Beginning at the heart the following branches of the aorta should be identified. Make a drawing of your dissection and indicate thereon what organ or region is supplied by each branch.

Branches of the Dorsal Aorta.

1. Coronary artery. This is a small artery that comes off the ascending aorta immediately as it leaves the heart. It supplies the heart itself.

2. Innominate artery. A large branch extending towards the head. It in turn gives off (a) the left common carotid, continues a short distance cephalad and bifurcates, forming (b) the right common carotid and (c) the right subclavian. The common carotids give off several branches, of which the external carotids are the largest. They supply the jaws and face. The internal carotid enters the cranial cavity. (Right subclavian described below.) Does the left common carotid in man arise from the innominate (manikin)?

3. Left subclavian. This arises near the base of the innominate. Except for origin the courses of the right and left subclavians are similar. The subclavians pass forward in the neck as far as the shoulder, where they turn abruptly into the arms. At the angle where each subclavian turn into the shoulder it gives off the vertebral artery. These arteries pass forward through the vertebrarterial foramina of the cervical vertebrae into the cranial cavity. At the base of the medulla they anastomose, forming the basilar artery. The basilar artery later divides, each division forming a connection with the internal

carotids. These arterial anastomoses form a circle at the base of the brain known as the circle of Willis. Reference will be made to the circle of Willis at the time of the study of the brain. The subclavian arteries upon passing into the arms are called the brachial arteries.

4. Intercostal arteries. A pair of these arteries lead off between each pair of succeeding ribs except that the first few pairs may arise from a single branch. Would you classify the intercostals as somatic or visceral arteries? The most caudal of the series of branches may pass to the lumbar region. These would then be called lumbar arteries.

5. Bronchial arteries. A pair of small arteries which pass to the bronchi, thence to the lungs.

6. Oesophageal arteries. These are a few small twigs passing to the oesophagus.

7. Coeliac axis. A rather large but short trunk which arises immediately below the diaphragm. It in turn gives off (a) the hepatic artery which supplies the liver, the right side of the stomach, the pancreas and duodenum; (b) the left gastric which supplies the lesser curvature of the stomach, and (c) the splenic, the largest of the three branches; it supplies small arteries to the stomach and pancreas, but the largest branch is to the spleen.

8. Superior mesenteric. A rather long and large artery which supplies the small intestines. It ramifies through the mesentery of the small intestine by a series of picturesque arcades.

9. Adrenolumbalis. Paired arteries which arise on either side of the aorta a little caudal to the superior mesenteric. They supply the adrenals, the lumbar region and sometimes the diaphragm.

10. Renals. Paired arteries to the kidneys. They branch just before entering the kidneys at the hilus. One or both may send a branch to the adrenals.

11. Spermatie ovarian. Small, paired arteries to the testes (ovaries). One or both may arise as a branch from the renals.

12. Inferior mesenteric. A single, rather small artery to the large intestine and rectum.

13. Lumbar arteries. Several pairs of arteries which come off the dorsal side of the aorta. They supply the muscles of the lumbar region.

14. Iliolumbalis. A pair of arteries passing laterally to supply muscles of the lumbar region.

15. External iliaes. A pair of prominent arteries arising in the pelvic region. They pass down the legs, where they are called the femoral arteries.

16. Hypogastric. These paired arteries mark the termination of the dorsal aorta. They supply the viscera and muscles within the pelvis and the gluteal muscles outside. The hypogastric arteries are of importance embryologically because from them branched off the umbilical arteries which supplied the placenta. What is the origin of the hypogastric arteries in man (manikin)?

17. Caudal artery. A small artery to the tail. It arises on the dorsal side of the aorta between the bases of the hypogastrics. The corresponding artery in man is the middle sacral artery.

Veins.

For the most part veins accompany the arteries and have the same names as their arteries, e. g., femoral vein, external iliac vein.

Among the large veins there are several important variations from this arrangement and these will be noted.

Compare the walls of arteries and veins. Which are thicker? Do the walls of veins collapse?

(1). Coronary sinus. This receives all the veins within the muscle of the heart itself. This sinus empties by a separate opening into the right atrium.

(2). Superior vena cava. This large vein enters the right atrium from above. It is the main thoroughfare for blood from the head, arms and thorax. Its first tributary is (a) the azygos vein which drains blood from the walls of the thorax. The next tributary is (b) the internal mammary which drains the ventral wall of the thorax, and finally (c) the innominate veins, the union of which marks the beginning of the superior vena cava. The innominate veins correspond fairly well to the

carotid arteries. They are formed by the union of the external jugular from the head and the subclavian from the arm.

(3). Inferior vena cava. This is the large vein coming from the posterior part of the body. It lies to the right of the dorsal aorta, between the azygos veins. It enters the right atrium. It clearly is the companion of the dorsal aorta. Its tributaries are (a) the hepatic veins; these are short veins from the liver. It is necessary to clean away some of the liver tissue to see them; (b) the phrenic veins. These collect blood from the diaphragm and empty it into the inferior vena cava as the latter passes through the diaphragm; (c) adrenolumbalis; (d) renal veins; (e) spermatic (ovarian) veins; (f) lumbalis; (g) iliolumbalis; (h) common iliacs. These in turn are made up of the external iliacs and hypogastric veins. The middle sacral vein (caudal) may enter the right or the left common iliac.

(4). Hepatic portal system. This is a system of veins which collects the food-laden blood from the intestines and stomach and conveys it through the portal vein to the liver. It leaves the digestive system at the duodenum in company with the bile duct, passes ventral to the epiploic foramen and enters the liver, where it breaks up into numerous ramifications. The portal vein is formed by the union of five tributaries which come together near one place. The largest of these branches is (a) the superior mesenteric which seems to be the continuation of the portal vein. Other tributaries named in order of diminishing size are (b) the gastrosplenic, (c) the gastroepiploic from the greater curvature of the stomach, (d) the coronary from the lesser curvature of the stomach, and (e) the pancreaticoduodenal. The inferior mesenteric vein joins the superior mesenteric.

Capillaries.

Capillaries are minute blood vessels which connect the distal extremities of all arteries and veins. Their walls are thin, being composed of only the endothelium, which is the innermost layer of larger blood vessels. It is through the walls of capillaries that the function of the blood is carried on, and the thin walls are an adaptation to this function. Practically all slide preparations of tissues contain capillaries with their enclosed blood corpuscles.

To see blood circulating through capillaries one or more of the following methods may be employed: (1) tail of a tadpole. Lay the tadpole on a slide and quickly view the capillaries in the tail. (2) Web of the foot of a small frog. Do not attempt to use the common bull frog for this on account of the web being too thick. Two persons should co-operate. One person should hold the frog while the other views the blood circulating in the capillaries of the web. (3) A 40 to 70 hour chick embryo. Remove the embryo from the egg in warm physiological salt solution. Transfer it promptly to a slide for microscopic examination. This is the most satisfactory material, but not always practicable to obtain. (4) Mesentery of any small mammal or lizard. The animal should be etherized and the mesentery spread on a slide for microscopic examination, care being taken not to disturb the connections with the main circulation. Be sure that the animal is killed without being allowed to regain consciousness.

Red Blood Corpuscles.

From slide preparations examine and draw as true to scale as possible red corpuscles of the following: deer, mouse, man, horse, frog, *Amphiuma*, camel.

List the animals named above according to the size of the corpuscles. What group of animals possesses non-nucleated corpuscles? Does the camel seem to be an exception?

NERVOUS SYSTEM.

Preliminary to the study of the nervous system it is advisable to prepare all nervous tissues to be studied. Open the cranium dorsally so as to expose the greater surface of the brain of a cyclostome, shark and dog or cat. Immerse the heads thus dissected in jars of ten per cent formalin for several days to harden the nervous tissue. See footnote (1) under Muscles.

The nervous system is the integrating system of the organism. It receives sensations, converts them into impulses and transmits them into the central parts of the central nervous system, where they become concepts, or these impulses may be directed from the central portions of the central system to muscles or glands, where they produce respectively contractions or secretions.

Anatomically the nervous system is conveniently divided into (1) the central nervous system which consists of the brain and spinal cord, and (2) the peripheral nervous system which includes the remainder of the nervous system, which in turn is composed of the sympathetic nervous system, the nervous parts of the sense organs and the so-called "nerves" of the body.

Functionally the nervous system may be divided into (1) sensory nerves, i. e., those which bear impulses towards the central nervous system, and (2) motor nerves which bear impulses to muscles or glands.

The entire nervous system is essentially a system of neurones, and a neurone is composed of (1) a cell body to which are attached (2) dendrites which receive and convey impulses towards the cell body, and (3) an axone which conveys impulses away from the cell body. The axone may give off a few branches known as collaterals, all of which terminate in fine branches called telodendria. (Review under Histology.)

Embryology.

The entire nervous system arises from the ectoderm of the mid-dorsal line. Examine slide preparations of chick embryos of not over 30 hours' incubation. The nervous system is here shown as a longitudinal groove in the mid-dorsal line. In the region of the head this groove is wider and deeper, foreshadowing the brain, while the posterior portions are to become the spinal cord. Slide preparations of cross sections of the embryos of chick and frog will show the nervous system after the groove has closed over the top in completing the formation of the neural tube. Make a drawing.

The peripheral nerves grew out from the central nervous system. In the region of the cord these outgrowths are known as the roots of the spinal nerves. The motor nerves grew out of the cord from its ventro-lateral aspect. The sensory nerves grew out of the ganglionic crest. This was a shelf-like structure which first appeared as an outgrowth from the dorso-lateral aspect of the cord. In the ganglionic crest arose a series of spinal ganglia and from these spinal ganglia axones grew in two directions, (1) peripherally to the skin, etc., and (2) centrally into the dorso-lateral aspect of the cord. (Consult Fig. 1.

Cross section slides of a 25-millimeter pig will show the neural tube with the dorsal and ventral roots extending themselves from the dorso-lateral and ventro-lateral regions.

What is the germ layer origin of the entire nervous system? The neural tube is lined with a thin membrane known as the ependyma. What is its embryological origin?

In the embryonic brain there may be distinguished three primary divisions known as the three primary brain vesicles. They are the (1) forebrain, or prosencephalon, (2) midbrain, or mesencephalon, and (3) hindbrain, or rhombencephalon. These divisions may be seen in most young chick embryos.

Cyclostomes.

With care remove the brain of a cyclostome. Identify the structures and parts, making use of Figure 3. The three major divisions and subdivisions of the brain are easily discernible.

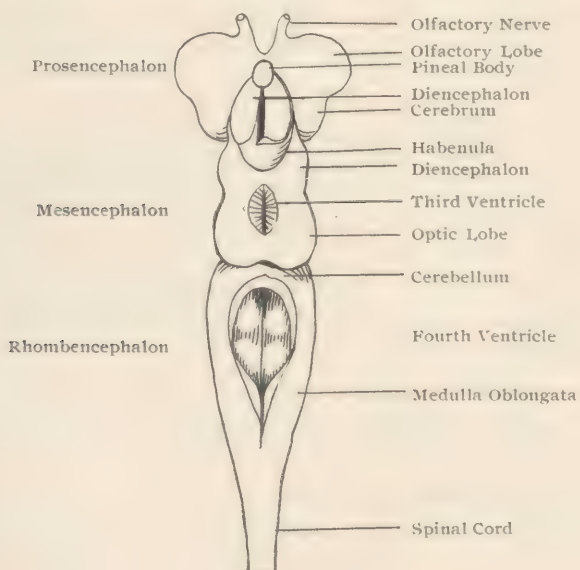


FIG. 3. Brain of *Petromyzon*, Dorsal view.

I. Prosencephalon. (a) Telencephalon, olfactory lobes, cerebrum; (b) Diencephalon, cerebral stem, habenula.

II. Mesencephalon, optic lobes, third ventricle.

III. Rhombencephalon. (a) Metencephalon, cerebellum.
(b) Myelencephalon, medulla oblongata, fourth ventricle.

Can you see any reason why the olfactory and optic lobes should be so large while the cerebrum and cerebellum are so small?

On the ventral surface of the brain are the stumps of the cranial nerves. Make an outline drawing of the brain, adding the cranial nerves as they are identified. The conventional numerals are herewith given the cranial nerves (K. 164).

I. Olfactory nerves, from the nose; sensory.

II. Optic nerves, from the eyes; sensory; they enter the brain on the ventral surface of the cerebral hemispheres.

Immediately behind the optic nerves is the low, flattened hypophysis resting on a rounded eminence, the infundibulum.

III. Oculomotor nerves arising behind the infundibulum. They run to the muscles of the eyes; motor.

IV. Trochlear nerves. They arise on the dorsal side of the brain behind the optic lobes. They go to the superior oblique muscle; motor.

V. Trigeminal nerves. These are the largest of the cranial nerves. They arise in the ventro-lateral surface of the rhombencephalon ventral to the trochlear nerve roots. As its name implies each nerve divides into three branches. It is distributed to the face; sensory.

VII. Facial nerves. They arise from the medulla posterior to the trigeminal. They supply muscles in the region of the head and neck; motor.

VIII. Vestibular. This is in close connection with the preceding. It enters the brain immediately ventral to the facial. It arises in the semicircular canals which are a part of the equilibratory apparatus; sensory.

X. Vagus nerves. They arise from the medulla behind the last mentioned pair. These nerves pass to the viscera; motor.

Shark.

Any type of elasmobranch will serve for this dissection. It is not necessary to remove the brain at once as the cartilaginous cranium is fairly transparent enabling the various structures

and especially the cranial nerves to be seen without actually uncovering them.

Begin the study of the shark's head by examining the sense organs and the cranial nerves connecting the sense organs to the brain. (K. 16 and 182 ffg.)

Remove the skin and some cartilage above and behind the eyes until the nervous structures are visible. Continue the dissection as necessary until finally the entire brain is removed. Nerves will be seen passing dorsal to the orbit on their way to the tip of the head. These nerves are the facial and the trigeminal. If the trigeminal be a sensory nerve, what can be its function in the tip of the snout?

A careful examination of the muscles of the eye will show that they receive three motor nerves, viz: the oculomotor, the trochlear and the abducens. Within the circlet of eye muscles will be found the large, round optic nerve.

By probing the nostrils it will be observed that they are sacs rather than passageways. If these sacs are uncovered from the dorsal surface the black nasal capsule may be examined. Find the light colored nervous tissue (olfactory bulb) applied to the posterior surface. From the olfactory bulbs olfactory tracts lead backward into the olfactory lobes of the brain.

The lateral line system of the head, previously studied under the heading of Integument, marks the location of the trigeminal nerve beneath the skin and serves as a guide for the dissection of that nerve and the facial.

The semicircular canals will be found on each side of the head lateral to the medulla. There are three semicircular canals and their dissection is practicable. Their function is equilibration. They are innervated by the vestibular nerve, which should be found.

Behind the vestibular nerves are the glossopharyngeal nerves which go to the first gills and neighboring regions of the pharynx. They are sensory and motor.

Behind the glossopharyngeal are the vagi nerves. These have a double origin in the medulla. One division (laterals) passes posteriorly and laterally to the lateral line of the trunk. The other division (jugular) passes to the gills behind the first and to the stomach and intestines.

A drawing of the entire brain and nerves should be made at this time (dorsal view), after which the brain may be removed.

Bisect the brain by a sagittal section. Identify the various structures by reference to Figs. 174, 176, 181 (K. 166 ffig. .

Mammals.

Spinal Nerves.

Spinal nerves are given off the spinal cord at regular intervals to emerge from the vertebral canal between the vertebrae. There will be, therefore, as many spinal nerves as there are vertebrae. In the basal portion of the neck these spinal nerves divide, unite and divide again in the formation of the brachial plexus, which finally, besides sending numerous twigs to surrounding tissue, sends three main trunks, (1) the radial, (2) the median, and (3) the ulnar, to the arm. In the lumbar region is the lumbar plexus, which sends two trunks to the leg: (1) the femoral nerve which enters the femoral region on the medial side of the leg in company with the femoral artery and vein; and (2) the sciatic nerve which enters the femoral region dorsal to the ilium and ischium bones.

These two plexuses should be identified.

Sympathetic Nervous System (K. 177).

This is the part of the nervous system which controls the involuntary muscles; that is to say, this system controls all the organs of digestion, all the glands, the dilation and contraction of the blood vessels, the dilation and contraction of the pupils of the eye, etc.

This system is closely interwoven with the rest of the nervous system, but some parts are easily observable and distinguished.

Inside the thorax and abdomen, underneath the peritoneum, lying on either side of the vertebral column are the sympathetic trunks. Each trunk consists of a continuous nerve trunk throughout the neck, thorax and abdomen, with an enlargement (sympathetic ganglion) corresponding to each intervertebral space. From each sympathetic ganglion it is possible to trace the following connections: (1) the connecting trunks passing up and down making connections with the other sympathetic

ganglia; (2) rami communicantes passing from each ganglion into the spinal nerves; (3) peripheral nerves passing from each ganglion medially and ventrally to join other sympathetic ganglia scattered throughout the thoracic and abdominal cavities, which ganglia in turn control the visceral organs. See Fig. 188 (K. 179).

The above mentioned structures are conveniently dissected in most mammals.

Spinal Cord (K. 144 and 173).

The relationships of the spinal cord, spinal nerves and vertebrae should now be examined. With the help of a bone saw and forceps remove a few vertebrae in block with the cord in situ. The vertebrae are less firmly attached to one another in the thorax. If two vertebrae be separated from each other and the cord severed between, the dorsal and ventral roots of the spinal nerves should be seen. (Review under Nervous System, Embryology.) The roots unite to form the spinal nerve at the point where the nerve leaves the vertebrae. An enlargement, the spinal ganglion can be seen on the dorsal root.

The cut surface of the cord shows two colors: the gray substance in the interior of the cord and the white substance forming the outer portions. The gray substance in cross section forms the well known "H." The limbs of the "H," properly called columns, serve to separate the white matter of the cord into four funiculi; viz: one dorsal funiculus, one ventral funiculus and two lateral funiculi. Make a sketch about two and one-half inches in diameter of a cross section of the cord to show the above mentioned structures. Refer to Fig. 154 (K. 146).

Further study of the cord will be made from slide preparations of cross sections of the cord of man or bear. These slides have been stained so as to give a blue color to the white or myelinated portion. The gray substance will be recognized by being less stained and by its many fibers and large nerve cells.

Add to your drawing of the cross section of the cord of a dog the following structures as they are identified on the slide: Dorsal septum, ventral sulcus, central canal, ventral and dorsal nerve roots, ventral white commissure (immediately dorsal to the sulcus), ventral gray commissure (immediately dorsal to the

white commissure), numerous white fibers passing from the gray substance outward into the white substance.

A high power examination of the white matter shows it to be composed of the ends of myelinated nerve fibers. These fibers are grouped into tracts or bundles which can be demonstrated only by the use of special methods. The tracts of the dorsal funiculus are mainly up-bound (afferent), that is to say they are sensory in function and their fibers carry impulses only towards the brain. The fiber tracts of the ventral funiculus are mainly out-bound (efferent). In the lateral funiculi there are both afferent and efferent fiber tracts.

Brain (K. 170).

By means of bone forceps carefully remove all bone from the hardened brain of dog or cat. Preserve the cranial nerves to as great a length as possible. The tough membrane enclosing the brain is the dura mater. Considerable difficulty will be experienced in removing it from around the cranial nerves due to the danger of pulling the cranial nerves loose from the brain.

The blood supply of the brain has been described under the headings of Mammal, Arteries, Left subclavian, to which reference should be made. The arteries there mentioned, viz: internal carotids, vertebrals, basilar, and the circle of Willis should be identified at this time.

Look for any biological advantage in the fourfold blood supply to the brain and the anastomoses of these four arteries.

After completing the examination of the arteries of the brain the arachnoid fibers in which the blood vessels are embedded and the blood vessels themselves may be removed. By reference to Plates IV and V identify the following parts of the brain: Cerebrum, olfactory lobes, olfactory tracts, cerebellum, pineal body, medulla, IV ventricle, optic chiasma, hypophysis, infundibulum, mamillary body, lateral fissures, pons, pyramids, cerebral peduncles, corpora quadrigemina, olives.

The cranial nerves should be taken up systematically. For so long a time the cranial nerves have been designated by num-

PLATE 4. Dorsal view of brain of dog. 1, olfactory nerves; 2, olfactory lobe; 3, median (sagittal) fissure; 4, pre-Sylvian sulcus; 5, cerebrum; 6, cerebellum; 7, vermis; 8, fourth ventricle; 9, medulla oblongata; 10, ventral roots of spinal nerve; 11, dorsal roots of spinal nerve; 12, dorsal sulcus of spinal cord; 13, spinal nerve.

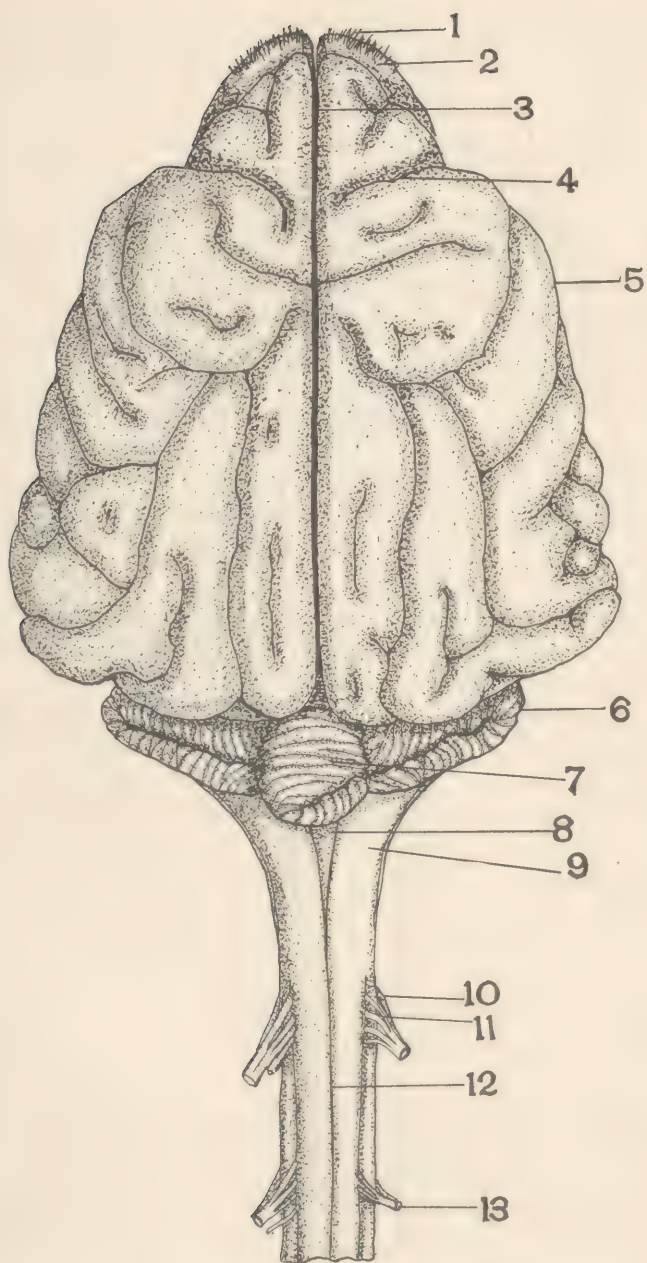


PLATE 4.

bers that these numbers have become almost synonymous with the name of the nerve. Although the numbers now have no significance in a strict sense, they are, for historical reasons, here given.

A drawing of the ventral surface of the brain should be made and the cranial nerves added and labeled as identified.

Bisect the brain by a clean cut through the sagittal plane. In the sagittal plane identify and draw by the aid of Plate VI and Fig. 181 (K. 172) the following structures:

Olfactory lobes, cerebellum, arbor vitae; this is the white, tree-like structure in the cerebellum, medulla oblongata, fourth ventricle; this is the open triangular space in the roof of the medulla. It extends forward under the cerebellum, thence forward under the velum, thence forward as the aqueduct of Sylvius into the midbrain. Here it widens dorso-ventrally into the third ventricle. The third ventricle is very narrow, and unless the knife went true through the mid-line the third ventricle will have been missed.

Commissures. In the center of the third ventricle is a circular commissure known as the intermediate mass. Dorsal to the third ventricle is a longitudinal strip forming the roof of the ventricle; this is the fornix. Dorsal to the fornix is a still larger commissure and the largest in the brain; it is the corpus callosum. The anterior angle of the corpus callosum is the genu; the posterior angle is the splenium. The anterior commissure will be found at the anterior junction of the fornix and corpus callosum. The optic chiasma is a commissure. The posterior commissure is small, lying behind the third ventricle where the latter enters the aqueduct. The pons is a commissure ventral to the medulla.

Infundibulum, the hollow stalk leading from the third ventricle to the hypophysis.

PLATE 5. Ventral view of brain of dog. 1, olfactory nerves; 2, olfactory tract; 3, cerebrum; 4, optic nerve; 5, optic chiasma; 6, optic tract; 7, hypophysis; 8, oculomotor nerve; 9, trochlear nerve; 10, facial nerves; 11, auditory nerves; 12, glossopharyngeal nerves; 13, vagus nerves; 14, cerebellum; 15, abducens nerve; 16, hypoglossus nerve; 17, ventral fissure of spinal cord; 18, spinal nerve; 19, maxillary division of trigeminal nerve; 20, mandibular division of trigeminal nerve; 21, ophthalmic division of trigeminal nerve; 22, semilunar ganglion (Gasserian); 23, spinal cord; 24, pons.

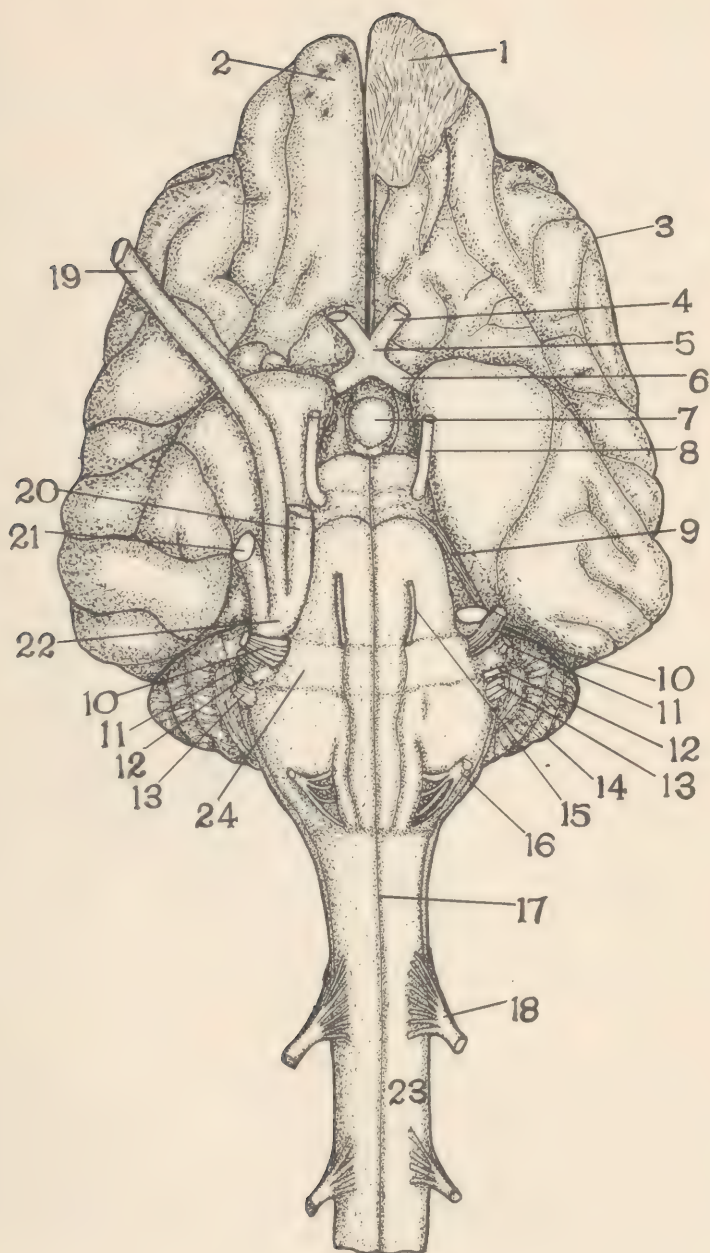


PLATE 5.

Mamillary body, a rounded eminence immediately posterior to the infundibulum.

Corpora quadrigemina, in front of the cerebellum. They appear as four hillocks on the dorsal surface of the cerebral peduncles. They contain the terminations of the visual tracts. They form the roof of the aqueduct.

Velum, the thin, membranous roof of the aqueduct extending from the corpora quadrigemina to the cerebellum.

Pineal body, a small, non-nervous body immediately dorsal to the anterior end of the corpora quadrigemina.

Pre-optic recess, the forward extension of the third ventricle terminating at the lamina terminalis.

Dissect away the gray matter of the cerebellum, leaving the white arbor vitae. Note that the fibers of the arbor vitae are connected to the other parts of the central nervous system by three peduncles. They are named, beginning with the most anterior, (1) brachium conjunctivum, (2) brachium pontis, (3) restiform body.

The cerebral ventricles, also called the lateral ventricles, may be seen underneath the corpus callosum. The connection between the third ventricle and the lateral ventricles (foramen of Monroe) may be seen by probing in the lateral anterior extensions of the third ventricle.

A portion of the roof can now be removed to obtain a view of the radiations of the corpus callosum. Now remove the corpus callosum entire, exposing the lateral ventricles. Fibers of the fornix will be recognized extending diagonally backwards and curving laterally and ventrally. Scrape away these fibers of the fornix and underneath will be seen a body whose fibers run parallel with the fibers of the fornix; this is the thalamus.

PLATE 6. Sagittal section of brain of dog. 1, spinal cord; 2, central canal of spinal cord; 3, gray matter of spinal cord; 4, arbor vitae of cerebellum; 5, cerebellum; 6, velum; 7, choroid plexus of fourth ventricle; 8, fourth ventricle; 9, medulla oblongata; 10, pons; 11, aqueduct of Sylvius; 12, mamillary body; 13, hypophysis; 14, maxillary division of trigeminal nerve; 15, infundibulum; 16, mandibular division of trigeminal nerve; 17, optic chiasma; 18, preoptic recess of third ventricle; 19, optic nerve; 20, maxillary division of trigeminal nerve; 21, olfactory nerves; 22, intermediate mass or central commissure; 23, corpus callosum; 24, interventricular foramen (Monroe); 25, cerebrum; 26, Sylvian fissure.

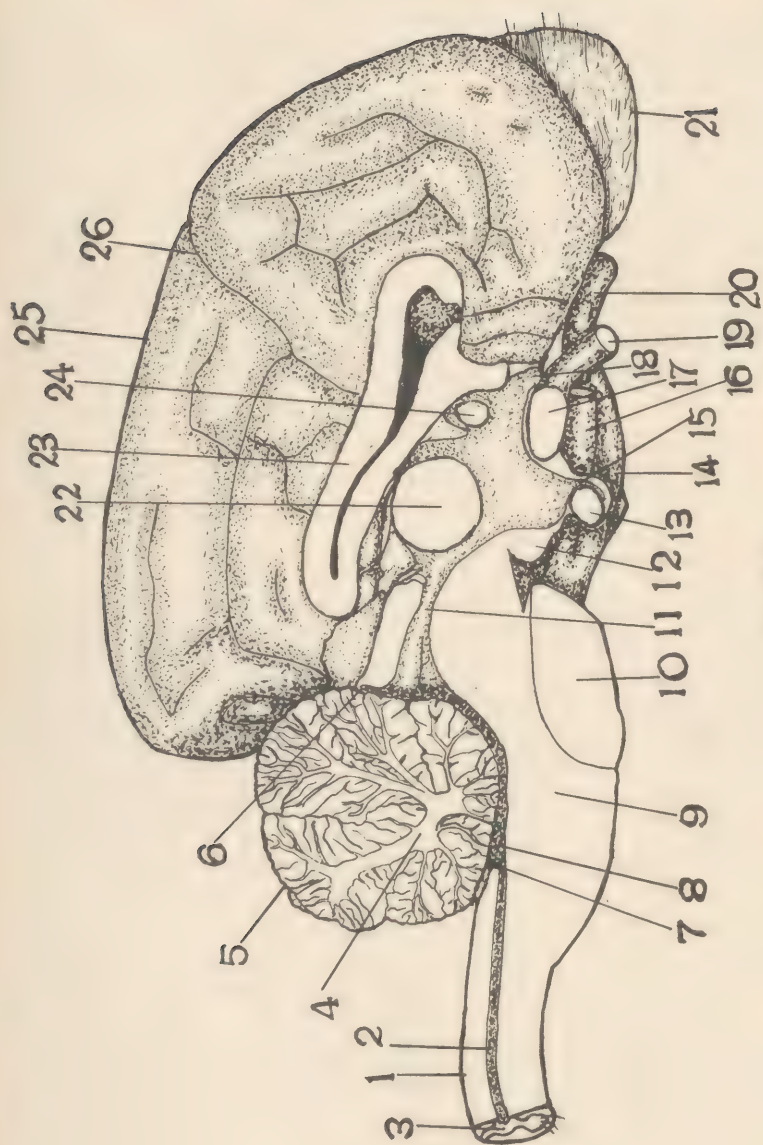


PLATE 6.

TABLE OF CRANIAL NERVES.

No.	Name.	Function and Distribution.	Superficial Attachment to Brain.
I.	Olfactory.	Sensory, nasal epithelium.	Olfactory lobes, rhinencephalon.
II.	Optic.	Sensory, retina.	Optic chiasma, diencephalon.
III.	Oculomotor.	Motor, four of the eye muscles.	Cerebral peduncles, ventral surface.
IV.	Trochlear.	Motor, superior oblique.	Cerebral peduncles, dorsal surface.
V.	Trigeminal.	Sensory, face, tongue, teeth, scalp.	Pons, forms the semilunar ganglion.
V.	Masticator.	Motor, chewing muscles.	Pons, accompanies the trigeminal.
VI.	Abducens.	Motor, lateral rectus.	Medulla at the posterior margin of pons.
VII.	Facial.	Motor, facial and platysma muscles.	Medulla, lateral, posterior margin of pons.
VII.	Glossopalatine.	Sensory, tongue, palate.	Medulla, accompanies facial nerve.
		Motor, salivary glands.	
VIII.	Cochlear.	Sensory, cochlea.	Medulla, posterior and near facial.
VIII.	Vestibular.	Sensory, semicircular canals.	Accompanies the cochlear.
IX.	Glossopharyngeal.	Sensory, tongue, pharynx.	Medulla, lateral surface.
		Motor, pharynx, glands.	
X.	Vagus.	Sensory, alimentary canal, lungs, heart.	Medulla, posterior near IX.
		Motor, alimentary canal, lungs, heart, larynx.	
XI.	Spinal accessory.	Motor, neck and shoulder muscles, pharynx, heart.	Medulla and upper part of cord.
XII.	Hypoglossal.	Motor, tongue.	Medulla, ventro-lateral surface.

SENSE ORGANS.

Eye (K. 213 ffig.).

The eyes of all vertebrates are so similar that it matters little which group is selected for this study.

Embryologically the eyes arose as optic vesicles from the forebrain. Examine slide preparations of the optic vesicles of chick embryos of about 48 hours' incubation. The lateral extremities of the vesicles dilate and simultaneously invaginate, forming a two layered, goblet-like structure known as the optic cup, the stem of the goblet being the optic stalk. The two layered cup thus produced is to become the retina. The outermost layer of the cup will become the pigmented layer of the retina, while the inner layer of the cup, being much the thicker, will produce the various layers of cell bodies found in the retina central to the pigmented layer.

The optic cup is not a perfect "cup" in that it contains a fissure extending from rim to stem. Optic nerves grow out from the cell bodies of the retina centrally towards the cavity of the eyeball, thence out through the optic fissure, along the optic stalk, through the optic chiasma and into the brain.

As the optic vesicles extended themselves from the brain towards the surface of the head, the skin covering the vesicles responded to the proximity of the vesicles by developing lenses. At first the skin thickened, then it began to invaginate, finally forming a sac with its opening to the outside. The opening then closed and the sac itself closed together, obliterating its own lumen, thus forming the lens. Follow Figs. 288, 229 (K. 213).

After the completion and union of the lens and optic cup the outer layers of the eyeball were added from the connective tissue. The first layer added outside the retina was the choroid, a highly pigmented layer. Then there was added outside this the tough, white, fibrous layer known as the sclera.

Examine one another's eyes for the following structures—a lens could be used to advantage: Pupil; iris; sclera; cornea, the transparent covering over the pupil and iris; conjunctiva, the epithelial covering over the front of the eyeball and the lining of the lids; tarsal glands, found in the lids opening at the margins; plica semilunaris, a fold of tissue over the inner corner of the eyeball, homologous to the nictitating membrane

of fowls, some amphibians and reptiles; *caruncula semilunaris*, the small eminence in the nasal corner of the eye; *papilla lacimalis*, the small papilla found on the margin of the lids near the nasal angle. Through these papillae are minute ducts through which the tears drain to the nasal cavities.

Bisect the preserved eye of dog or cat through the pupil and optic nerve. The plane of section should show the structures indicated on Fig. 231 (K. 216). Make a drawing about two and one-half inches in diameter of the bisected eye showing sclera, choroid, retina, lens, optic nerve, vitreous chamber, aqueous chamber (anterior chamber), posterior chamber, iris, pupil, cornea, conjunctiva, ciliary process, lens capsule.

Under what circumstances will the lens become more convex? Do we have a voluntary control over the curvature of the lens? The lens is under the control of what division of the nervous system? Why do animals which live under water possess lenses which are much more spherical than the lenses of animals that live on land?

Ear (K. 197).

Unlike the eye the ear is not equally developed among vertebrates. Fishes and urodeles have no ears: anura and reptiles have the middle and inner ear only, while amniotes have added the external ear.

Associated with the ear are two senses, (1) hearing and (2) equilibration. The organs of the latter senses are located within the inner ear and have no outward manifestations.

Frog.

Remove the lower jaw of a frog and find the short Eustachian tubes extending from the roof of the mouth to the tympanic membranes. Attached to the center of the tympanum is a long, slender bone, the columella. Its inner end connects with a second bone, the stapes, (and this in turn communicates through the fenestra ovalis with the cavity of the inner ear.

This cavity contains a fluid, known as the perilymph, surrounding a structure called the membranous labyrinth. The membranous labyrinth consists of a central mass called the vestibule, which is visibly composed of two parts, (1) a rounded lower portion, the saccule, which contains the auditory sense

organs, and (2) the elongated upper portion, the utricle, from which arise three semicircular canals occupying three different planes perpendicular to one another. The auditory and vestibular nerves pass from the vestibule to the medulla.

Mammals.

The ear of mammals consists of three obvious divisions: (1) the outer ear, which includes (a) the visible portion, or pinna, and (b) the external auditory meatus, the passageway leading from the pinna into the eardrum or tympanum. Inside the tympanum is (2) the tympanic cavity, and beyond the tympanic cavity is (3) the inner ear, the part where the essential sensory structures are lodged.

By means of bone forceps chip away the petrous part of the temporal bone of dog or cat in order to open the cavities of the middle and inner ear. The middle ear of dog or cat is found in the rounded bony masses, called the tympanic bullae, ventral to the external ears. In the middle ear find the tympanum separating the external auditory meatus from the tympanic cavity. Identify the three auditory ossicles. Attached to the tympanum is (1) the malleus; this connects with (2) the incus, and this in turn with (3) the stapes, which fits into the fenestra ovalis, the window leading into the inner ear. The tympanic cavity is connected to the pharynx through the long, slender Eustachian tube (See under Pharynx). It must, therefore, be lined with what germ layer? The Eustachian tube should be opened throughout its entire length.

The inner ear contains a fluid, the perilymph, and, as in frog, a membranous labyrinth. Here again the two senses occupy different portions of the labyrinth. A new structure appears in mammal not found in the frog, viz: the cochlea. This is the essential organ of hearing, and is like a snail shell in appearance. It is attached to the saccule. Find the vestibular nerve emerging from the utricle and the auditory nerve emerging from the saccule. The two nerves unite and enter the medulla.

The embryology of the ear may be studied from slide preparations of the embryos of chick of 48 to 70 hours incubation or of 10-millimeter pigs. On each side of the hindbrain will be seen a cavity lined with epithelium. This cavity is known to

give rise to the inner ear, and the epithelium of the cavity will become the sensory epithelium of the membranous labyrinth.

The middle or tympanic cavity originated in the first pharyngeal (hyomandibular) groove. The external auditory meatus developed from the outer portion of the same groove. The two layers of epithelium between these two cavities persisted and became the tympanum. Therefore the outer layer of the tympanum is of which germ layer? Observe the threefold origin of the ear. No other sense organ seems to have so complex an origin.

External ear—from the skin ectoderm.

Middle ear—from the endoderm of the pharynx.

Internal ear—capsule, from mesoderm (bone); labyrinth, from mesoderm; sensory epithelium, ectoderm.

Lateral Line System (K. 194).

This system has been previously described under the heading of Integument. Its innervation was described under Nervous System, Shark. It should be reviewed at this time.

The function of this system is not certainly known, but is believed to receive wave sensations of low frequency. (K. 194.)

Olfactory Sense (K. 204).

In cyclostomes the olfactory organs consist of a single nostril placed on top of the head and a single olfactory capsule associated with the hypophysis. In fishes the olfactory organs consist of paired nostrils leading into paired olfactory capsules. The walls of these capsules are well provided with nerves (olfactory nerves) which upon leaving the capsule enter at once the olfactory bulbs which are closely applied to the capsules. From the bulbs the olfactory tracts lead back into the brain. The above should be reviewed under the heading of Nervous System, Shark.

The nasal cavities of the dog or cat were examined at the time the respiratory system was being studied. In all air breathers the olfactory system is associated with the respiratory system. Review that part of the respiratory system which pertains to the olfactory sense.

Gustatory Sense (K. 204).

In fishes the gustatory epithelium may be not only in the mouth but around the lips and snout and, as in the case of the

cattfish, on long barbels. In all terrestrial animals the gustatory epithelium is inside the mouth and for the most part limited to the tongue.

The gustatory end organ is called a taste bud. It is oval and composed of long, slender, spindle-shaped cells which in cross section appear in layers, giving to the bud the well known onion appearance.

The inner ends of the cells are enclosed in a net of nerve fibers; the outer ends are about flush with the surface of the epithelium and are stimulated chemically by materials being "tasted."

Draw a bud from a slide preparation of the tongue of cat or rabbit.

SKELETON.

(K. 42.)

For purposes of study the skeleton may be divided into (1) the axial skeleton consisting of the skull and vertebral column, (2) the appendicular skeleton which includes the bones of the appendages and the girdles to which they are attached, (3) the visceral skeleton comprising the structures which support the gill arches, and (4) the dermal skeleton which consists of plates of bone found in the skin of certain vertebrates, mainly the "lower" vertebrates. The scales of fishes and reptiles, the plates of turtles, feathers of birds, hair of mammals, and the shell of the armadillo are all examples of the exoskeleton of vertebrates. These structures have been studied under the heading of Integument and will not be discussed farther.

Skeletal material may be either bone or cartilage. In cyclostomes and elasmobranchs there is only cartilage.

Cyclostomes.

Cut a lamprey eel in two by a transverse cut. In the dorso-central region of the section find the round notochord. Around it is a thin, tough, connective tissue sheath, the notochordal sheath. What is the germ layer origin of this sheath? (K. 51.) Around the sheath is a thin layer of investing cartilage, the vertebral column. Clean a small portion of it to determine whether or not it is segmented.

Dorsal to the vertebral column is the spinal cord. Is it invested in cartilage or in any way protected?

Remove the skin and some muscle tissue from the gill region. This will suffice to uncover portions of the gill basket, a cartilaginous framework which supports the gill chamber. Is this structure strictly homologous to the visceral skeleton of other vertebrates? (K. 84.)

In the skull identify the labial cartilages which support the buccal funnel, the anterior dorsal cartilages and the posterior dorsal cartilages in the roof of the skull and the otic and the olfactory capsules.

Do cyclostomes have an appendicular skeleton?

Elasmobranchs.

In the skull of a shark identify Meckel's cartilage, that is, the cartilage of the mandible, the pterygoquadrate or upper jaw, the roof of the cranium, the hyoid cartilage posterior to Meckel's cartilage and the hyo-mandibular cartilage which connects the angle of the jaw to the cranium. Do you consider that the upper jaw is loosely or firmly attached to the cranium? Learn the meaning of the terms amphistylic, hyostylic and autostylic (K. 79), and determine by dissection which term applies to your specimen.

In the visceral skeleton of a shark determine the number of branchial cartilages. Identify the hyoid arch, the mandibular arch, the first branchial arch. To which division of the skeleton, cranial or visceral, do the following cartilages belong: lower jaw, upper jaw, hyoid arch, hyomandibular cartilage? (K. 80.)

Remove a section of the vertebral column from the tail region. Is a notochord present? The central, circular portion of a vertebra is the centrum. To each centrum are attached two arches, viz: the neural arch, on the dorsal side and the haemal arch on the ventral side. As suggested by the name the haemal arch contains the caudal blood vessels, caudal artery and caudal vein.

Make a sketch of a cross section of a caudal vertebra, showing the above mentioned structures.

Remove an entire vertebra. Is it concave at both ends? Define the terms procoelous, opisthocelous, amphicoelous, and amphiplatyan, and decide which term applies to the shark vertebrae (K. 49). Do you consider the material between the vertebrae to be vestigial notochordal material?

The appendages of the shark consist of median or unpaired fins and paired fins. Determine by dissection the character of the bony connections of the median fins, that is, do the rays of the fins continue to the vertebral column or are they interrupted by joints?

Observe that the paired fins never exceed two pairs. They are designated according to their position. The anterior pair is called the pectoral fins; the posterior pair the pelvic fins. The paired fins are attached to skeletal girdles known respectively as the pectoral and pelvic girdles. Remove these two girdles for further study. These girdles resemble each other in that they are both closed ventrally and open dorsally, roughly resembling the letter U. In the pectoral arch the ventral portion is known as the coracoid; the dorsal portion is the scapula. In the pelvic arch the ventral portion is the ischiopubis; the dorsal portion is the ilium.

Mammal.

Vertebral Column and Thorax.

Remove a vertebra from the lumbar region of a dog or cat. To show all structures it should be drawn from two points of view, the end and the side. The cylindrical bony mass is the centrum. The arch which encloses the spinal cord is the neural arch. The foramen through which the spinal cord passes is the vertebral foramen. The dorsal spine arising from the crest of the neural arch is called the neural spine. In which direction is the neural spine directed in the lumbar region? In the thorax? In what region are the spines the longest? The anterior and posterior articular processes will be understood from their names. In the region of the thorax there appears on each vertebra a pair of transverse processes attached to the sides of the neural arch. They support the ribs.

Remove a vertebra from the cervical region. Draw the end view. Observe the smaller canals, the vertebralarterial canals, each side of the foramen. These serve to accommodate the vertebral arteries on their way to the brain. The vertebralarterial canals are evidently peculiar to the cervical vertebrae only.

The two anterior vertebrae are unusual and require special attention. The first one is called the atlas. It possesses two

smooth surfaces for the reception of the two occipital condyles and has no centrum. The second vertebra is called the axis. It has a tooth-like process known as the odontoid process, attached to the centrum extending forward through the foramen of the first vertebra, and acts as a pivot for the rotation of the head between the first and second vertebrae.

Observe the origin of the skeleton in slide preparations of cross sections of a 26-millimeter pig embryo. Developing cartilage will be noticed around the notochord. The cartilage immediately around the notochord is to become the centrum. Processes extending from the centrum dorsally and around the spinal cord are the neural processes in process of forming the neural arch. These areas of developing skeleton should be recorded by a sketch.

How many ribs has a dog? How many has man? Is the sternum of a dog jointed? If so, how many joints has it? Compare with the sternum of man. The three divisions of the sternum of man are named, beginning with the uppermost, (1) the manubrium, (2) the gladiolus, and (3) the xiphoid.

Skull.

A dog's or cat's skull and a human skull with the "caps" sawed off afford good material for the following study. Other fragments of skull showing vertical and horizontal sections are helpful.

Most of the bones of the skull are paired therefore in the following list; unless otherwise specified it is understood the bones are paired.

Occipital. Single; this is the most posterior bone of the skull. It is perforated by the foramen magnum through which passes the spinal cord.

Parietal. These bones meet in the mid-line of the cranium to form its roof. They are in front of the occipital. They are separated from each other by the median or sagittal suture.

Frontal. Two bones lying directly in front of the parietals. The sagittal suture continues between them. Are there one or two frontals in man?

Squamosals. These lie dorsal to the auditory meatus. Each one articulates with the parietal above, the sphenoid in front, the occipital behind, and articulates with the lower jaw. The

zygomatic process extends forward from this bone towards the orbit. It contributes to the formation of the zygomatic arch.

Tympanics. Each bone forms a ring around the auditory meatus, and ventral to the meatus it enlarges to form the hollow tympanic bulla. The bulla contains the auditory ossicles and has been described under the heading of Sense Organs, Ear. These two bones, viz: the squamosal and the tympanic, unite in the human skull to form the temporal bone. The tympanic bone extends inward as a roof over the inner ear. This is called the petrous part of the temporal.

Auditory ossicles. Review under the heading, Ear, Mammals.

Sphenoid. Single; this bone lies in the floor of the cranium in front of the occipital. It sends processes laterally to the posterior margins of the orbits, and wedges in between the frontal and the squamosal. These lateral extensions are called *alae* (wings).

Ethmoid. Single; this bone is also in the floor of the cranium anterior to the sphenoid, where it forms the roof of the nasal cavities. In it is a sieve-like structure through which the olfactory nerves pass, known as the cribriform plate. The ethmoid appears in the medial wall of the orbit.

The above mentioned bones all border on the cranial cavity. They are, therefore, called cranial bones. The following bones do not contribute to the formation of the cranium and are therefore called facial bones:

Nasals. Two small bones above the nasal apertures.

Pre-maxillaries. Two bones forming the sides and floor of the nasal cavities. The incisor teeth are inserted into the pre-maxillary bones. Are pre-maxillaries present in man?

Maxillaries. These are lateral and posterior to the pre-maxillaries. They hold the remainder of the upper teeth and form most of the roof of the mouth. A large foramen in the maxillary in front of the orbit transmits the ophthalmic division of the trigeminal nerve.

Palatines. These bones meet in the roof of the mouth behind the maxillaries. They constitute the hard palate. The last two named bones, viz: the maxillaries and the palatines, form a horizontal septum which separates the mouth from the nasal cavities.

Lacrimal. Small bones found in the anterior, medial surface of the orbits. Foramina through the lacrimals give passage to the lacrimal ducts which convey the tears from the eyes to the nasal cavities. In case of the lemurs (lowest order of primates) the lacrimals are extended out over the face and the lacrimal ducts are outside the orbit.

Vomer. Single; it serves as a septum between the two divisions of the nasal chamber.

Jugal. These bones complete the lateral sides of the orbits. They send long processes backward to connect with the zygomatic processes from the squamosals, thus completing the zygomatic arches. This bone is homologous to the zygomatic or malar bone of human anatomy.

Nasal Conchae. These are the thin, paper-like bones inside the nasal cavities. In life they are covered with olfactory epithelium.

Mandible. The lower jaw in most mammals excepting the primates consists of two bones joined at the mid line. In man there is but one bone. The union in the mid-line is called the symphysis mandibuli.

Sinuses. These are air spaces inside the bones of the skull. The frontals of quadrupeds contain numerous such spaces which give the bone a spongy appearance. The function of these spaces is doubtless to give lightness and protection.

Other sinuses are found in the sphenoid, the ethmoid and the maxillaries. All sinuses connect through ducts with the nasal cavities. In human anatomy the maxillary sinuses are the largest and should be observed.

The hyoid is a slender, U-shaped bone with two pairs of horns. It is found in the throat. Some of the muscles of the tongue attach to it.

To which division of the skeleton, axial or visceral, do the following bones belong: hyoid, parietal, squamosal, jugal, occipital, palatine, mandible, frontal, maxillary. (K. 80.)

Appendicular Skeleton.

In the fore leg identify and clean the following bones:

Humerus. This is the bone in the proximal segment of the leg. Its upper extremity is rounded off into a head forming with the scapula a so-called ball and socket joint. The distal

extremity of the humerus has two rounded surfaces called condyles which articulate with the two bones of the lower segment of the leg.

Radius and Ulna. These are the two bones of the lower segment of the leg. The ulna has at its proximal end a hook called the olecranon, which articulates with the humerus. The head of the radius is rounded to enable it to rotate. In the cat there is considerable rotation or twisting on the part of these bones, but in dog there is very little. The primates have ample rotation in these bones. The radius is on the thumb side of the forearm.

Carpels. These are seven bones found in the wrist. In man there are eight. They occur in two rows, one row articulating with the radius and ulna above and the other row articulating with the—

Metacarpels. These are the five bones of the hand. In plantigrade animals the metacarpels lie parallel with the ground when the foot is placed on the ground. Examples of such animals are the bear, raccoon, opossum, rabbit, man. In digitigrade animals the metacarpels are elevated at the proximal end so that in a certain sense the animal walks on its toes. Such animals are the cat, dog, cattle, horse.

Phalanges. These are the bones of the fingers. The number of digits may vary, but the linear number is quite consistently three for the inside digits.

The arms are attached to the pectoral girdle. In man this girdle is more complete. The dorsal portion consists of the scapulae. Two broad, flat, triangular bones extending from the head of the humerus towards the vertebral column. The ridge extending along the dorsal surface of the scapula is the spine of the scapula. It terminates distally in a process, the acromion, which contributes to the glenoid fossa which receives the head of the humerus.

The clavicle in man is the bone commonly called the collar bone. It extends from the acromion to the upper extremity of the sternum.

There is no clavicle in the dog and only a very slender one in the cat.

A coracoid bone is present in amphibians, birds and some reptiles, and in some forms a procoracoid bone is present. The

coracoids have disappeared in mammals, but a vestige of the coracoid may be seen in the coracoid process of the scapula. This process lies near and anterior to the acromion process.

In the hind leg the bones are generally homologous to the bones of the front leg, not only as regards position but even as to structure.

Front leg.		Hind leg.
Humerus.....	homologous to.....	Femur
Ulna.....		Fibula
Radius.....		Tibia
Carpals.....		Tarsals
Metacarpals.....		Metatarsals
Phalanges.....		Phalanges

The hind leg, in addition to the above mentioned bones, possesses a patella, or knee cap. This is placed in front of the knee joints and acts as a pulley for the tendons of the anterior thigh muscles and holds the tendons away from the joint which aids the leverage of the muscular action. The patella, not being closely articulated with any other bone, is classed as a sesamoid bone.

The pelvic girdle has shown a developmental tendency to strengthen itself by the method of fusion of bones. In contrast with this the pectoral girdle shows a tendency toward freedom of movement at the sacrifice of some strength.

In the pelvis there are two bones which grip the vertebral column. These two bones are the innominate bones of human anatomy, and the portion of the vertebral column lying between the innominates shows a tendency to fuse. This fused portion of the vertebral column is the sacrum, and is another indication of the strengthening process of the pelvis.

In the embryo the innominates are composed of three separate bones. All three bones center in the formation of a cavity, known as the acetabulum, into which fits the head of the femur. The bone extending dorsally from the acetabulum to the sacrum is the ilium, the largest of the three. Extending posteriorly from the acetabulum is the ischium, and extending ventrally is the pubis. The pubes join in the mid-ventral line forming the symphysis pubis. The ischium and pubis join distally, thus forming a large foramen, known as the obturator foramen.

The bones should be memorized.

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